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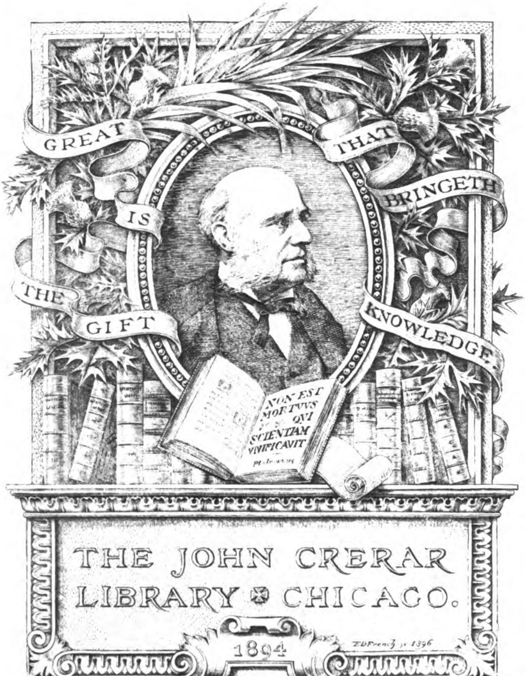

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FORD CAR, TRUCK
AND TRACTOR REPAIR

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FORD CAR, TRUCK AND TRACTOR REPAIR

BY

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FIRST EDITION

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PREFACE

The purpose of this text is to give the mechanic a complete understanding of the mechanical principles underlying the operation of the Ford Car, Truck and Fordson Tractor. Merely knowing quick methods of assembly and disassembly of the various units is not enough. The really competent repairman should have a thorough knowledge of the mechanical and electrical action of every unit of these machines, in order to get at the cause of the various troubles, as well as repair them.

When we consider Ford simplicity from a mechanical standpoint, as it is exemplified in the Car, Truck or Tractor, the public requirements of these, together with the fact that the great majority of them are operated by persons with little or no experience in the handling of machinery, they stand as remarkable machines.

The operating expense of Ford Cars, Trucks and Fordson Tractors has assumed a large place in the budget of the American people. It is the duty of every dealer, and dealer's mechanic to reduce this expense to the minimum. With the thought in mind of forwarding this good work, this text has been prepared.

ALFRED A. GOOD.

DETROIT, MICH.,
February, 1922.

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FORD CAR, TRUCK AND TRACTOR REPAIR

CHAPTER I

THE FORD CHASSIS AND ITS COMPONENT PARTS.

The following paragraphs covering the chassis and its component parts, are intended to give the student an outline of the methods of suspension and bracing, used in the assembling of the Ford Chassis. Some points regarding the necessary care in removing and replacing the different units will be covered in this chapter which will not be found in the detailed study of the various other units elsewhere in this work.

The chassis is that part of an automobile comprising all parts except the body and rear fenders.

General Construction.—In the general construction of the Ford Chassis, the main points attained have been light weight and simplicity of construction without sacrifice of strength or endurance. The Ford Chassis is made up of four main groups or assemblies, which are the Front Axle Assembly, Rear Axle Assembly, Power Plant Assembly, Dash and Steering Assembly, and the smaller units comprising the final assembly.

Unit Study.—Regarding their location, connection and adjustment when in the chassis.

The Frame.—Serves as a foundation for all the units of the car, and holds all units in line with each other. The frame is

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made up of two long straight side members and front and rear cross members. Side members are made of channel section pressed steel. Front cross member is bent down to form a support for the semi-elliptic transverse spring. The rear cross member is bent upward to fit the arch of the rear spring and to add more strength.

Dimensions.—Length of side members of Model "T" 100 in.
Length of side members of Model "TT" 123 29-32 in.
Width of front cross member of Model "T" 23 in.
Width of front cross member of Model "TT" 23 in.
Width of rear cross member of Model "T" 25 7-8 in. to center of bracket holes.
Width of rear cross member of Model "TT" 30 in. to center of bracket holes.

In assembling frame, the hot riveting method is used. By this method the rivet contracts as it cools, thus binding the parts and giving added strength. By using a hammer to test each rivet any looseness in the joints can be located.

Brackets.—Are used to support the body, running boards, truss rods, fenders, lamps, and control rod quadrant. They are attached to the frame by rivets, excepting fender and lamp brackets, which are bolted. Riveting helps to prevent these parts working loose and rattling.

Truss Rods.—Are used on the running board brackets to give added support to the frame. They must be inspected quite often to insure their being tight and taking the strain properly.

The Cooling System.—The thermo-syphon type is used. On account of the frail construction of radiators it is necessary to use flexible supports to relieve radiator strain through frame

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distortion. The Ford radiator is supported (1) by brackets, (2) springs placed over and under bolts, and, (3) by a stay rod to the dash. Care must be exercised in removing the radiator because of its frail construction. When out of the car it must be placed so that the cooling surface will not be damaged in any way. Lay flat on face on padded wood runners, or place on special rack. In replacing, secure bracket bolts so that spring tension is not too great.

Hose Connections.—Are placed between radiator inlet and outlet connections and the engine. They provide a flexible connection between these two units, and eliminate strain on the flanged connections.

Fan.—Located just back of the radiator. Its purpose is to assist in cooling by suction of the air around radiator tubes. The fan belt should be inspected often and tightened when necessary, by means of an adjusting screw in fan bracket. Do not get too tight.

The Engine.—Is supported by three point suspension. Front end bearing is supported in a trunnion block carried by the front cross member of the frame. Brackets riveted and brazed to each side of the flywheel housing are supported by frame side members and secured by bolts and lock nuts. A wooden block is placed in channels of the frame and one bolt passes through side of frame and one through top of frame side member. This method of support permits a certain amount of rocking or twisting of either front corner of frame without affecting the power plant. In supporting the side brackets to the truck frame, the bolt through each side member is not tightened but fits loosely, and the bolt resting on the block and through top of the side member is fitted with a coil spring between arm and nut. This allows more play and relieves the strain on the brackets.

How to Remove:

1. Drain oil

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2. Drain water and remove radiator connections
3. Remove radiator
4. Disconnect all wires and commutator case
5. Shut off gasoline at tank and remove feed pipe from carburetor and remove throttle connection lever from carburetor
6. Remove fan belt and fan
7. Remove retaining cap from ball joint connection of radius rod to pan
8. Remove trunnion support cap at front end of engine
9. Remove bolt from left and right side bracket supports holding pan to frame
10. Remove nuts and bolts holding dust pan to crank case
11. Remove the four bolts at the universal joint ball cap
12. Lift engine from frame.

If the engine is to remain out of service for any length of time it should be taken down and thoroughly lubricated inside and out. Paint the cast surfaces with iron paint, and use 600-W oil to oil the parts. Remove spark plugs and replace with wood plugs.

The Transmission.—In the Ford Car we have unit power plant construction, that is, the transmission built into the engine. The purpose of the transmission is to transmit the power from the crankshaft, through the drive shaft, to the rear axle, to permit change of speed through change gears, and to reverse the direction of driving the car.

Adjustment.—In adjusting the clutch, remove transmission cover door under the floor boards, jack up one rear wheel, throw clutch in high, turn the starting crank so the clutch fingers come into a convenient position to remove cotter keys. Give set screw one half to one complete turn to right, to tighten clutch. Do the same to all three set screws. If the car has a tendency to creep forward when cranking it indicates that the clutch lever screw, which bears on the clutch lever cam has worn,

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and requires an extra turn to hold the clutch in neutral position. To tighten brake and reverse bands, turn the adjusting nuts on the shafts to the right. To tighten low speed band, loosen the lock nut at the side of the transmission and turn the adjusting screw to the right.

Gaskets.—The Ford Gaskets are made of paper, felt, cork, copper and asbestos. Remove gaskets with care and some of them may be used many times. Before replacing cylinder head gasket, clean metal faces thoroughly, and line up gasket with bolt holes before replacing cylinder head.

The Dash Assembly.—Provides a place for the control devices used on the car, i. e. coil box, ignition terminal, carburetor, dash adjustment, etc. It is secured to the frame by two brackets and four bolts fastened through frame side members. In removing, disconnect steering post bracket, disconnect ball arm, disconnect all wires. leave these connected to the dash assembly, remove bracket bolts used to support it to the frame and complete assembly may be removed. The steering assembly is assembled to the dash, and both the assemblies are placed on the car as a unit. This is one of the most important parts of the car. Safe steering devices have made high speed possible. The steering assembly is secured to the frame by steering post bracket with three bolts, and, to the dash by four bolts to the flange.

To remove, disconnect ball arm at drag link, remove bolts at steering post bracket, and remove dash bracket bolts from frame. In replacing, be sure all bolts are drawn tight and locked with cotter keys. Inspect ball sockets around ball arm at lower end of steering post, if loose, file caps. Inspect caps at other end of tie rod. Inspect reduction gears. All adjustments on drag link must be made in such a manner that parts will not bind. Keep these connections tight, but do not fit so closely as to cause the wheel to turn hard. Have as little play

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as possible without binding. Lubricate well. Use light grease on all parts. Pack gear case with grease.

To remove steering wheel, remove nut on top of the post, and drive the wheel off the shaft using a block of wood and a hammer. Exercise care and do not batter the threads.

Rear Axle.—Supports the rear end of the car, carries the final drive mechanism, and provides axle shaft housing. It is attached by four bolts connecting universal ball cap to transmission case and cover, and two nuts holding spring perches to rear axle housing flanges.

To remove, jack up car to remove weight from spring, remove four bolts at universal joint ball cap, disconnect brake rods, remove nuts holding spring perches to rear housing flanges, and withdraw rear axle assembly as an entire unit. To replace, use the reverse process.

Torque and thrust is provided for, by use of a tube or housing surrounding the drive shaft, and, by radius rods extending from rear axle at a point near each wheel to a yoke attached to the drive shaft torque tube just in the rear of the power plant.

Lubrication.—Of the rear axle is practically automatic as far as the differential and bearings are concerned. Do not put too much lubricant in the rear axle housing, as the gear takes up too great a quantity and distributes it to the shafts. The revolving action of these shafts carries the lubricant to the outer ends, and, if the felt washers are not in first class condition, the lubricant works out to the brake drums. The axle housing bell should be about one third full. Inspect about every thousand miles to make sure that the level is kept constant. Inspect rear axle at regular intervals. Keep all connections well tightened, especially the torque equipment.

Universal Joint Coupling.—This kind of coupling permits rotation of the drive shaft even though it is at an angle with the crankshaft. This angle is necessary because the differential

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and driving gears in the rear axle are carried lower than the engine. For this reason, some driving coupling must be provided which is capable of compensating for this lack of alignment. The ball housing surrounding the joint permits the turning and twisting of the axle as the wheels travel over uneven surfaces.

Location of Brakes.—On transmission brake drum, and drums carried by the rear wheels. The service brake is of the external contracting type. The emergency brake is of the internal expanding type. To operate the service brake push right hand pedal forward, this movement constricts a fabric lined brake band around the transmission brake drum, to which is attached the drive plate assembly, which is connected to the drive shaft, by a universal joint coupling. This controls the movement of the rear wheels through the medium of the bevel gears. To use the emergency brake, pull the hand lever back as far as possible. Fastened to the control rod are two pull rods which are connected to the cams which expand the brake shoes in the rear wheel drums. The brake shoes are semi-circular, made of cast iron, and anchored to the rear axle housing flanges by one bolt. They are operated by the cam and coil spring. Brakes should be inspected frequently and kept in proper adjustment. All joints should be kept well lubricated.

Care of the Wheels.—The wheels require considerable attention. They must be cleaned often and repainted. Front wheels should be jacked up and tested for smoothness of running and side play. Inspect for split balls, examine bearings, cones and ball races. Clean bearings frequently and keep hubs well filled with grease. To remove front wheels, remove hub cap, cotter pin, castle nut, and spindle washer, after which you can take out the adjustable bearing cone and remove the wheel. Exercise care in replacing, so that the cones and lock nuts are replaced on the same spindle from which they were removed,

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otherwise you will find there is a liability of splitting the threads, which are left on the right and right on the left side of the car. To remove rear wheels proceed as above, then use a wheel puller to remove the wheels from the tapered shaft, to which they are locked with a key. When replacing, be sure nut on axle shaft is tight and cotter pin in place.

Wheel Base.—Is the distance from the center of the front hub cap to the center of the rear hub cap, which is the center of the road contact of the front and rear wheels. This distance is 100 in. on all Ford cars except the one ton trucks, on which it is 123 in.

Tires.—Considerable wear and expense can be saved by careful inspection and repair at regular intervals. Keep all cuts cleaned out and filled with gum. If punctured, clean the hole and vulcanize. Heat, dirt, water and oil are tires' worst enemies. Avoid locking wheels with brakes, running in car tracks or ruts, or bumping tires against the curb. Always keep tires well inflated; twenty pounds per inch of cross section is considered to be about right. When car is idle for any length of time, jack it up to take the load off the tires.

The Front Axle Assembly.—The front axle assembly includes the spindles and spindle arms, front springs, spring perches, spring shackles, radius rods, tie rod and drag link.

Construction of Axle.—Some designers use steel tubing, this gives a strong light axle, but when once bent it is very difficult to restraighten. Of any design, the solid construction or the Ford I beam is considered the most practicable. It is forged from a solid bar of Vanadium Steel, and not only is light but strong as well. The front axle is placed low enough so that it protects the other parts underneath the car. *If the axle is bent it must be straightened cold. There is danger of distempering the steel if heated,* as it is given a special treatment at the factory.

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Spindle Assembly.—Consists of the wheel axle, steering arm, inner or stationary cone, the outer cone, the steel washer and hex castle nut. The steering arm and ring cone are tight fits and must be pressed into place, the arm held by a hex castle nut and cotter pin. In order that the bolt may slip easily through the tie rod yoke and steering arm, the hole in the arm for this purpose is lined up carefully after the arm is secured. The right hand spindle is threaded left hand and the left hand spindle the opposite way. The right spindle is controlled by the steering device, the other moves accordingly, being joined to the first by a tie rod which is adjustable. The tie rod is placed back of the axle where it is better protected.

The Radius Rod.—Prevents the axle from misalignment, keeps it from being turned over and receives the drive or push of the car, transmitting it directly to the front axle.

The Tie Rod.—Or connecting rod connects the two spindle arms. The drag link is the rod connected to the yoke of the right spindle arm by a ball and socket joint, and to the ball arm of the steering device by a ball and socket joint.

Alignment of Wheels.—*Camber* is the outward flare of the wheels at the top, which is 3 deg. on the Ford car. It is measured by the angle of each spindle below horizontal. The camber is not adjustable as it is provided for in the forging of the spindle.

Gather is the toe in of the wheels at the front, measured on a plane horizontal with the axle. It ranges from 1/8 to 1/4 inch on the Ford car. The amount of gather may be changed by turning the yoke at the left end of the tie rod. The gather may be lost by a bent tie rod.

Castor is the effect obtained by tilting the front axle backward at the top, 5 1-2 deg. in the Ford Front Axle. It makes steering easy, helps the car to hold the road and gives added strength.

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The Tread.—Is the distance between the center line of ground contact of the wheels on opposite sides of the car. The Ford car is standard tread, which is 56 in.

Clearance.—Is the distance from the lowest part of the car to the road and is approximately 10 in.

Removing Front Axle.—Jack up car, remove wheels, disconnect ball arm from drag link, disconnect radius rod at ball joint, detach front spring by removing two cotter pinned bolts from spring shackles on each side. Disconnect radius rod from axle by removing cotter pins and hexagon nuts. In replacing the front axle, be sure that all bolts, nuts and cotter pins are in place and well secured.

Springs.—Semi-elliptic transverse springs are used on the Ford car. The semi-elliptic spring is built up of a series of laminations or leaves of steel, graduated in length so that the longest member is at the bottom, and the shortest at the top. The lowest leaf is turned at the ends to form the eyes. The eye carries the bushing which secures the spring to the pin. Small bands of steel called rebound clips are placed around the ends of the leaves to keep them from separating under the rebound. The spring shackles are steel strips which fasten the ends of the springs to the spring clips. The shackles form a hinge joint which is necessary to provide for the lengthening of the springs as it deflects under the load. Spring perches form the support for the springs.

Care of the Springs.—The springs should be inspected frequently. See that all clips and bolts are tight and cotter pins in place. Keep springs well lubricated. When overhauling, disassemble springs, and polish with emery cloth, pack with graphite and reassemble. Keep them painted to prevent rusting. F-170 is the paint used on the chassis at the home plant, and may be bought at any of the Ford Branches.

Construction of Muffler.—The muffler is so constructed that

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the gas may be passed from a small concentric chamber, to a larger one, and then to the third or largest chamber, from which the gasses pass into the atmosphere. In passing through these three chambers the gasses cool, and the pressure is reduced until there is scarcely any noise when it finally passes into the outside air. The muffler is located underneath and near the rear end of the car, to enable burned gasses to be passed out without annoyance to passengers, also to reduce the possibility of fire. It is attached by two bolts to frame side member. The exhaust pipe connects to the exhaust manifold on the engine through a flange coupling or union, and at the muffler it slips into the forward end.

The muffler should be removed occasionally and thoroughly cleaned. Soak in kerosene if necessary to soften the carbon deposit. Clean all the openings between the chambers. Tighten all connections securely when replacing to avoid gas leakage and rattle.

Ignition and Lighting System.—The Ford magneto is the flywheel type. It is an alternating current generator with a stationary armature, and a revolving field of permanent magnets. It delivers low tension current alternating sixteen times per revolution. The magneto furnishes the "Primary" or low tension current. An Induction Coil or transformer is used to intensify or "Step Up" the low tension current produced by the magneto to a high tension current, so it will have enough voltage to jump the air gap at the spark plug. The "Commutator" or timer determines the instant at which the spark plug will fire.

The Ford wiring system is very simple. The high tension wires to the spark plugs are different lengths so as to reach the plug intended. The primary wires are black, red, blue and green. Inspect all connections and contact points for looseness. Keep all connections clean and securely fastened. The commutator should be kept cleaned and well oiled at all times. Keep spark plugs clean and gap adjustment correct which is 1-32 in.

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Starting System.—All cars are equipped with a starting system of the two unit type. It consists of a six volt D. C. generator, which is secured to the front of the engine on the right side by a bracket and three head screws. The six volt D. C. starting motor is secured to a flange on the left side of the transmission cover by four head screws. The starting motor is geared to the flywheel, which has a shoulder cut on its outer circumference, and the gear mounted upon it, and held concentrically by the shoulder and to the side by sixteen screws which pass through the side of gear, through magnet supports, through flywheel and peined on opposite side. The generator is geared to the large time gear.

A six volt battery is furnished with the equipment. The current for the starter and lights is supplied directly from the battery when the engine is stopped.

Fuel System.—The gasoline tank is under the seat in roadster, under left front seat in sedan, in rear compartment of coupe, and under front seat of touring car.

In removing the tank, shut off gasoline at sediment bulb, and, disconnect the feed line. Take out the bolts or screws and remove tank. Handle the tank with care, and do not dent. In replacing, secure all connections well. Inspect pipe line for pin holes or wear. Care should be exercised in filling tank, stop the engine, prevent spilling and put out all open flame lights on or near the car.

The sediment bulb is secured to bottom of tank. This contains a fine wire gauze strainer, which removes all water and dirt. Bulb should be drained often. The carburetor is located on the right hand side of the engine. Its purpose is to vaporize the fuel, and to measure and mix fuel in proper proportion to suit all engine speeds.

To remove the carburetor from engine:

1. Shut off valve at gasoline tank, and drain carburetor.

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2. Disconnect gasoline line from carburetor.
3. Remove hot air pipe.
4. Disconnect wire from choke valve lever.
5. Remove throttle rod from head of spray needle.
6. Remove bolts holding carburetor to intake manifold and save gasket. In replacing reverse the order.

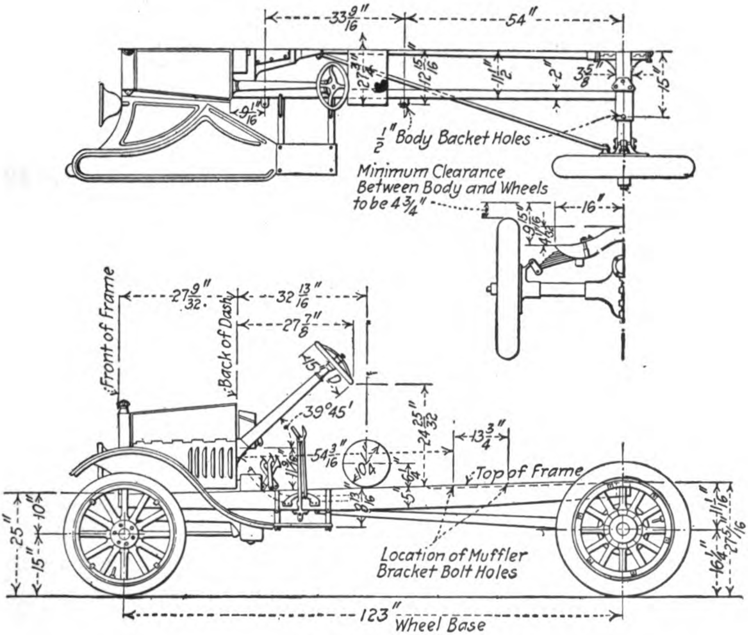

Fig. 1

General Lubrication.—Lubrication prevents excessive wear, and thus saves parts, minimizes repairs and the frequency of adjustments and replacements. The splash system of lubrication is used in the Ford engine. Keep crank case filled to the mark. Frequently inspect oil and grease cups; keep supplied with good oil and grease. Oil commutator often. Periodically

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inspect and lubricate the springs, axles, drive shaft, universal joint, fan pulley and shaft, crank handle bearing and wheels.

Questions and Answers on the Ford Chassis

Q. Why are leathers placed between frame and springs? Why under crank case arm?

A. On the rear spring leathers are used only when proper alignment cannot be secured by an iron to iron fit. On the front spring leathers are used to reduce vibration.

Q. At what degree should front axle be placed in car?

A. Front axle is placed in car with 5½° angle or approximately ¼ in. tilt back.

Q. How many leaves in front and rear springs?

A. Seven in front and eight in rear—T. T. seven in front and nine in rear.

Q. Why are four nuts used on each truss rod?

A. To keep secure, and as locknuts.

Q. How much oil or grease should be put in motor; in universal joint; in rear axle differential case, during chassis assembly?

A. One gallon of oil in motor, in universal joint four ounces, one and one-fourth lbs. in differential case.

Q. Why is grease used where motor is attached at front end; why on radius rod ball?

A. To aid in reducing friction as there is more or less movement of those parts when the car is in motion.

Q. How much throw does the slow speed pedal have? Why?

A. 1⅝ in. throw allowed, so that no difficulty will be had in securing neutral in the transmission.

Q. When should the lock washer be placed on magneto contact post with reference to magneto wire?

A. Lock washer should be placed on top of magneto wire, between wire and nut.

Q. How much gap should a spark plug have?

A. $\frac{1}{32}$ in. gap.

Q. How would you set a spark (by position of commutator cover) without a gauge?

A. When spark is fully retarded lead rod connection on commutator case should be ¼ in. past center of fan bracket bolt.

Q. On which side of commutator loom should the prime rod wire be placed?

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A. Prime rod should go between commutator loom and motor.

Q. Why is a spring put on radiator stud? On commutator?

A. Spring is placed on radiator stud to reduce vibration between the car and radiator. Spring is placed on commutator to allow for free movement of the case.

Q. How much water should be in radiator?

A. Water in radiator should be just below level of overflow pipe.

Q. Give the sizes of the different cotter pins, and where used on chassis assembly.

A. $\frac{3}{32}$ in. x $\frac{3}{4}$ in. spindle and spring perches.
$\frac{5}{32}$ in. x $\frac{5}{8}$ in. connecting rod and tie rod.
$\frac{3}{32}$ in. x 1 in. on U bolts.
$\frac{1}{16}$ in. x $\frac{1}{2}$ in. on all $\frac{3}{8}$ in. nuts or studs.
$\frac{3}{64}$ in. x $\frac{1}{2}$ in. commutator.
$\frac{1}{8}$ in. x 1 in. axle shaft nuts.
$\frac{3}{32}$ in. x $\frac{1}{2}$ in. on brake rods.

Q. Name places where grease and oil are used on chassis assembly when car is in actual use.

A. Springs, spring perches, spindle bolts, connecting rod, tie rod, ball joint, differential, rear axle roller bearings, universal joint, motor, front, motor connection, fan pulley, commutator, steering gear, steering gear bracket bushings, brake shoes, front wheels and crank.

Q. How is the steering assembly attached to the car?

A. By means of bolting steering post bracket to frame with three bolts, to dash with four bolts, to front axle, by means of the ball arm.

Q. How is the ball arm fastened to the steering post? Describe its purpose.

A. The ball arm is fastened to the steering post with Woodruff key and castellated nut. It transmits the power applied to the steering post when the wheel is being turned to the connecting rod through the connecting rod to tie rod and wheels.

Q. What is the steering gear bracket and to what is it fastened?

A. The steering gear bracket is a bushed casting bolted to the frame holding the steering post, lead and throttle rods in place.

Q. What threads are on the front axle spindles, and why?

A. Left hand threads on the right wheel, right hand threads on the left wheel. This causes nuts to have a tendency to tighten instead of loosen.

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Q. Are the planes of the front wheels parallel? Why?

A. The planes of the front spindle axles are not parallel. Each is inclined 4°. This 4° gives the wheels the necessary 3 in. flare out at the top.

Q. How far should gas throttle on carburetor be left open, and where should the throttle be set on this point, and why?

A. The gas throttle on the carburetor should be left open far enough so that motor will have an idling speed with the throttle and spark levers at top of quadrant.

Q. How are wheels removed?

A. Remove hub caps, cotter keys, nuts and cone in the case of the front wheels, wheels will then pull off.

Q. How is the front axle removed?

A. Disconnect spring perches and radius rod ball joint, steering arm connection; front axle assembly may then be removed.

Q. How is the rear axle assembly removed?

A. To remove rear assembly disconnect ball cap, brake rods and spring perches; assembly may then be removed.

Q. What would you do when you first start the motor and it runs without hitting on all cylinders?

A. Examine ignition and carburetor systems.

Q. When motor has been running previously but will not start after you have changed cam gears or shafts, where would you look first for cause of trouble?

A. Examine for properly meshed time gears.

Q. What causes a backfire when starting a new motor or one just overhauled?

A. Generally improper mixture.

Q. Give directions for starting a troublesome engine, when all conditions are correct for starting but it will not go.

A. Engine is probably flooded—prime with cylinder oil and gasoline.

Q. Where would you look for trouble if the engine stopped suddenly?

A. Either out of gasoline or ignition short.

Q. What causes the motor to lack power and run irregularly at *low* speeds?

A. Improper mixture, spark retarded too far.

Q. What causes the motor to lack power or run irregularly at *high* speeds?

A. Mixture too lean, weak magneto or magnets too far from coils owing to end play in crank shafts.

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Q. How can you tell which cylinder is missing fire?

A. By testing plug with screw driver, etc., stopping action of coil unit.

Q. How is a weak coil unit detected?

A. A weak coil unit may be detected by interchanging coil units.

Q. How does a short circuit occur?

A. A short circuit occurs when a conductor interposes on an electric current circuit and causes a circuit before the original predetermined circuit has been reached or completed.

Q. Where should throttle lever be set in cold weather when priming a motor equipped with a Holley carburetor? With a Kingston? Why the difference?

A. In cold weather the throttle lever on a Holly carburetor should be set about three notches down on the quadrant, five on a Kingston. This difference is due to the fact that the Holly has a slow speed or auxiliary mixing chamber.

Q. Where should the levers be set when engine is ready to crank?

A. When starting spark lever should be within one or two notches at the top of quadrant and gas lever three notches.

Q. What is the best position for the spark lever when driving the car?

A. When driving the spark lever should be advanced as far as possible and still maintain maximum engine efficiency. This may be determined by the "feel" of the motor.

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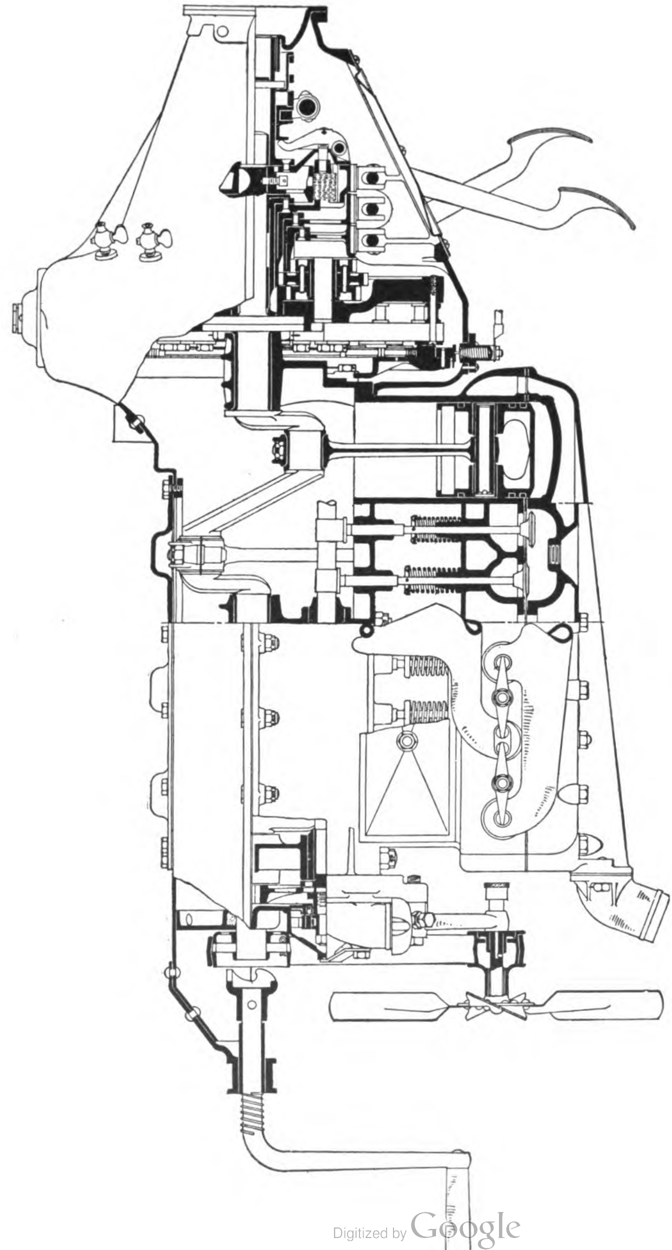

Fig. 2

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CHAPTER II

ASSEMBLY AND REPAIR OF THE FORD MODEL "T" ENGINE

Summary of Ford Engine Construction.—The Ford Model T Motor is a 4 cylinder, 4 cycle, internal combustion gasoline engine, with a 4 in. stroke and a 3¾ in. bore. Valves are of the poppet type arranged on one side of the cylinders, known as L head construction. Cylinders are cast en bloc and water jacketed, the upper part of the crankcase containing the crankshaft bearings, being integral with the cylinders. The water jacketed cylinder head containing the combustion chambers is removable from the cylinder case. The engine and transmission are a unit and this unit power plant is supported in the chassis frame on the three point principle.

Cylinder Case.—The cylinder case is an iron casting containing the four water jacketed cylinder bores, 8 valve parts with manifold passages, valve spindle guides, camshaft bearing bushing supports and, crankshaft bearing supports. The cylinder head containing the combustion chambers is cast separately from the case and is bolted thereto by 15 bolts threaded into the top of the case.

Cylinder Rolling.—The cylinder bores in which the pistons are to slide, after the boring and reaming operations vary in diameter from 3.748 inches to 3.479 inches. They are then rolled to a diameter of 3.750 in. with a special power driven rolling tool. This tool cylindrical block with small hardened steel rollers pivotally fitted around its circumference at an angle of 12 degrees from vertical. In operation, when the tool is revolved

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within the bore, the small rollers are pressed against the walls with a combination of sliding and rolling motion which produces a hard, smooth and polished surface. Oil is used to aid in the polishing.

Water Jacket Tests.—In the side of the cylinder case near the manifold ports are three 13-16 in. countersunk holes in the water jacket which are necessary for locating and removing the core in making the casting. These holes are plugged with small cupped steel dics, peined into the countersink. At this point in the preparation of the case the water jackets are subjected to a hydraulic pressure of 40 to 60 lbs. per square in. to test for possible weakness or leaks in the jacket walls. If the water jacket is found free from defects, the case is passed on to the valve seating machines.

Valve Seating.—The valve seat in the cylinder case is simply a bevel or chamfer of the sharp edge of the valve port hole. The valve port hole is 1 5-16 in. in diameter and the face edge of this hole is milled to form a countersink of 1 23-64 in.—1 29-64 in. in diameter. This countersink is of covex profile of 1-4 in. radius, which gives a hairline contact with the flat seat of the valve. Valve seats made in this form do not require a grinding operation to produce gas tight contact, and minimize the possibility of carbon deposits between seat and valve because of the rounded surface and the line contact.

Steam Holes.—In the top face of the cylinder case are five 1-4 in. steam holes entering different portions of the water jacket. When the cylinder head is in place these holes connect with five similar holes in the cylinder head jackets and allow the escape of air or steam which otherwise would form in the lower jacket in pockets, impeding circulation. The water circulates through the three larger passages between cylinder and head jackets.

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Dimensions of Case.—Length 22 9-16 in. (outside of cylinder chambers); 21 25-32 in. (at main bearings)

Height 10 5-8 in. (variation 1-32 in.)

Width 9 1-2 in. (at base)

Valve ports exclusive of seats 1 5-16 in.

Manifold port (6) 1 1-8 in. with 1 1-4 in. countersunk 1-8 in. deep.

Cylinder bores are 3.750 in. diameter and 6.752 in. long.

Cam shaft bearing support holes; diameter of front hole 1.374 to 1.375, center 1.372 to 1.373 rear; .9985 to 1.000.

Diameter of valve stem guide hole .3125 plus.

Diameter of push rod guide hole .437 plus. Cylinder head bolts are 7-16 in. diameter with No. 14 U. S. standard thread.

Valve Assembly.—The first assembly operation is the fitting of valves and springs in the cylinder case. The valves are fitted at this point so that the seat will be protected from injury in subsequent assembly operations. Valves are guided by the spindle hole in the case, and, are held in the seated position by a spring encircling the guide boss in the case at one end. At the other end by a collar, held by a small pin passing through a hole near the end of the valve stem. The valve spring is 3 in. long and 1 in. in diameter. When compressed by the washer and locking pin fixed to the valve stem it exerts a pressure of about 20 lbs. in holding the valve seated.

Dimensions of Valve.—Material; valve stem is made of cold rolled steel, and valve head of cast iron.

Diameter of head and upper edge of valve seat 1 15-32 in.

Diameter of lower edge of valve seat 1 17-64 inches—1 9-32 in.

Width of valve seat 3-32 in. ground at an angle of 45 deg. to stem center.

Thickness of head 3-16 in.

Stem diameter .3105—.312 inches.

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Length upper seat edge to plane through end of stem 4.974 inches.

Spring collar pin hole .110—.113 in. diameter, and 4 19-32 in. from valve seat line.

Rough Bearing Capping.—The upper half of the main crankshaft bearing supports are cast integral with the cylinder case. These supports are semi-cylindrical and are lined with a bushing of high pressure babbitt metal molded by the aid of a jig bar and held in place by lugs of the babbitt which fits into the casting. Caps of semi-cylindrical shape and lined similarly with babbitt metal form the complete crankshaft bearing when bolted in proper position. The caps are bolted to the cylinder case with .012 in. steel liner or shim; this being the rough capping operation preparatory to boring the bearings to size.

Boring Main Crankshaft Bearings.—The main bearings are bored in large lathes using boring bars, the cylinder case being held in a jig making use of the camshaft bearing holes as locating points. The case is held in this manner during the boring, as any variation of the distance between the crank and cam shaft bearings affects the meshing of the timing gears when these are assembled. The bearings are bored to a diameter of 1.248 in.—1.249 in. Boring bars are run through the bearings twice to insure a smooth and accurate job. After the boring, the edges of the babbitt are filleted to a radius corresponding to that on the crankshaft bearings. The babbitt extends over both ends of the long rear bearing because this bearing must take care of the end thrust of the crankshaft.

Hanging Crankshafts.—The crankshaft of the Ford engine is a drop forging of vanadium steel with four crank throws and three main bearings. The crank throws are all in one plane, i. e., 180 deg. apart, the two outside throws pointing in the same direction and the two inside throws in the opposite direction. The small gear is keyed to the shaft by means of a Woodruff key. It is made of vanadium steel, and has 24 spiral teeth.

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The main crank bearings have a radius of 3-16 inches machined at their edges. These take care of end thrust and make a stronger shaft than if the edges were cut square. After the cylinder case leaves the boring operation, the bearing caps are removed and the .012 in. liners taken out. Previous to removal, the caps are marked so that when replaced they will be in the same position as when bored. The coil holes in the cylinder case bearing are now punched out and countersunk. The oil hole in the rear bearing is usually clear so that it needs only to be countersunk, while the center and front bearing oil holes are choked with babbitt. The case hole of the center bearing will be found about half way between the center of the bearing and the front edge, while that of the front bearing will be found at approximately the middle point of the bearing half.

The edges of the babbitt in the case bearings are now filed with a flat rasp to an angle of 45 deg. with the lower face of the case. The groove thus formed when the cap is assembled acts as an oil lead for the bearing and also as a clearance to take care of babbitt pressed out during the subsequent "running in" of the bearings. The ends of the bearings are also filed smooth, then the crankshaft is fitted in the case. The crankshaft end play is determined by the variation between length of the rear bearing, and should not be more than .004 of an inch. Note that expansion in length of crankshaft due to heat in operating engine is forward from the rear, or long bearing. Any rearward movement would effect the gap between coils and magnets. The center and front bearings have from 1-32 in. to 1-16 in. end clearance which allows for expansion and lubrication. The oil grooves of the caps are filed and the caps are placed over the shaft bearing using the marks mentioned above to determine correct location. The cap is now "rocked" over the round shaft and two or more brass shims of .002 in. thickness are applied until the rock of the cap shows a .004 in. or .005 in. clearance between case and cap

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edges. The caps are then bolted down and the bearings are "run in" on a belting block at a speed of about 200 RPM for the period of one minute. The bearings during this process are pressed to conform to the shaft and a smooth even contact between shaft and bearing results.

Dimensions of Crankshaft Bearings:

Crankshaft, front 2 in.	Center $2\frac{3}{16}$	Rear $3\frac{1}{8}$ in.
Case, front $1\frac{15}{16}$ in.	Center $2\frac{1}{8}$ in.	Rear 3.118/3.120
Cap, front $1\frac{15}{16}$ in.	Center $2\frac{1}{16}$ in.	Rear 3/118-4/120

Principal Crankshaft Dimensions.

Length 25 5-32 in.

Length of connecting rod bearings 1.495 in.—1.505 in. on crankshaft.

Diameter of all bearings 1.248 in. also a standard undersize of .010 in. for main bearings and .025 in. for connecting rod bearings.

After the belting operations, the bearings caps are removed and the bearing surfaces inspected. If these bearings are in good condition, the caps are oiled, replaced, and bolted down with same tension as previous to removing.

Fitting Camshaft.—The camshaft is a vanadium steel forging with eight ground cam surfaces and three main bearings. The shaft is driven by means of spiral gearing at half the crankshaft speed. Its duty is to raise the valves from their seats at the proper time during the piston's cycle, and also to control the action of the commutator roller. The front and center bearings of the camshaft are assembled on the shaft before insertion in the case. The center bearing is of cast iron reamed, the front bearing of cast iron babbitt lined, the babbitt having previously been reamed and "run in" to size on a special machine. The bearings are split in half and are assembled on the shaft bearings by means of a spring clip snapped around the middle circumference. The center bearing is fitted with a liberal amount of play so that the shaft can

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line itself up properly. The rear camshaft bearing bushing is of cast iron pressed into the case and reamed with a reamer guided by the two forward bushing supports. The 48 tooth camshaft timing gear is also assembled on the shaft before fitting in the case. The gear is secured to the camshaft by means of two dowel pins driven into dowel holes in the flange of the shaft and the web of the gear. These pins are 7-16 in. long and have a 5-16 in. diameter at one end and 3-8 in. diameter at the other; the small end fitting in the camshaft flange. At an angle of 11 deg. ahead of the dowel pin center line on the camshaft gear, will be found a "O" mark under one of the spaces between the gear teeth. It is essential that this mark be set opposite the toe of the first cam in order that the valve timing and ignition be correct. A 13-16 in. x 16 U. S. thread locknut is screwed on to the shaft till the gear is firmly held against the flange. Before camshaft and push rods can be inserted in the case the ends of the valves must be lifted a half inch or so. This is accomplished by placing wedges between valve heads and seats. Push rods are now inserted and the shaft with bearings and gear assembled is forced through the bearing support holes until the bearings are in contact with their respective case holes. Set screw holes in the bearings are lined up with the corresponding holes in the case and the end of the shaft is tapped lightly with a rawhide hammer until the large gear of the camshaft is about to mesh with the crankshaft gear. The large and small gears are turned so that the gear tooth space marked "O" of the crankshaft gear meshes with the tooth marked "Ford" on the crankshaft gear and the shaft is driven into place. The timing gears should have a small amount of play or back lash in the teeth. If gears are too tight, they will hum or grind when the engine is in operation; if too loose they will produce noise by slapping back and forth. This play should be within the limits of two and four thousandths clearance between meshed teeth.

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A test measurement of the case distance between outside of crankshaft and at front of motor and edge of camshaft bearing hole allows the variation from standard to be approximated for by the fitting of a slightly oversize or undersized gear on the camshaft. This measurement should be 5.220 in. with a .002 in. over and .003 in. undersize limit allowed. The above measurement is correct when the motor is expanded from heat due to the belting operation of crankshaft bearings. If the motor case is cold, the distance should be 5.218 in. with the same variation limits.

Camshaft Dimensions:

Camshaft length 22-23/32 in.
Type N Vanadium Steel.
Diam. of end bearing .7488. Diam. middle one same as end.
Diam. of front bearing same as end.
Length of end bearing 1¾ in. Length of middle bearing 2 7-16 in.
Length of front bearing 1.967 in.
Width of cams 7-8 in.
Diam. of heel of cam 13/16 in.
Greatest diameter of cam 1 1-16 in.
Flange diameter 1¾ in.
Flange width ¼ in.
Dowel holes .3120—.3125.
Thread, big thread 13/16 in. x 16 U. S. F.
small thread 9/16 in. x 18 S. A. E.

Push Rods

Material Type N Vanadium Steel Heat treated.
Length 2-11/32 in. over all.
Diam. stem .4355—4365.
Diam. head 1 in.

Fitting Pistons and Connecting Rod.—The piston and connecting rod are mediums by which the expansive energy of the exploded gas within the cylinder is transformed into useful

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work in turning the crankshaft and on their proper fitting depends to a large extent the efficiency, balance and quiet running qualities of the engine. The piston and connecting rod, having reciprocating or "back and forth" motion, require considerable energy to overcome their inertia at the beginning and end of each stroke. This inertia representing a decrease in efficiency of the motor's power; productiveness increases with the speed of motion and also with a decrease in weight of the moving parts. For this reason pistons and connecting rods are designed and built for lightest possible weight compatible with strength. For the lighter the weight the less the inertia. The Model T connecting rod is a Type A A Vanadium Steel forging of I beam section with a babbitt bushed bearing box at one end and at the other a clamp to encircle and hold the wrist pin. The Model T connecting rod is 7 in. long between center of bearing to center of clamp hole. The babbitt bushed bearing is made in halves with removable cap held by two bolts with castellated nuts so that it can be assembled about the crank bearing. The cap is assembled on the rod and the bearing broached with .003 in. paper shims between the edges of cap and rod before being assembled in the engine. The width of the crank bearing box is 1.495 in. —1.505 in. and the width of the wrist pin clamp is 63/64 in. x 1-1/64 in.

The Piston.—The Model T piston is a gray iron casting, of softer material than the cylinder bore in which it is to slide so that the piston rather than the cylinder will receive the wear, it being more economical to replace pistons than cylinder castings. Cast iron, despite numerous attempts to lighten pistons by the use of aluminum alloys and steel, still remains the standard piston material for the following reasons: First, its expansion coefficient is about the same as that of the cast iron cylinder. Second, because of the cheapness and ease of molding and machining the material. Third, it gives a good bearing surface. Fourth, it possesses necessary strength and

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resists distortion. The piston is made as long as possible in order that it may have a large bearing surface, thus giving longer wear. Long pistons also avoid "cocking" due to angular pressure of connecting rod. The diameter of the piston at the top is about .010 in. smaller than at the bottom, or skirt. This is to compensate for expansion due to the intense heat to which the upper part of the piston is subjected. The top edge of the piston is beveled in order to conform more clearly to the shape of the combustion chamber which is of rounded profile. This bevel also avoids a sharp edge which might overheat, causing preignition.

The Piston Pin.—The piston pin is a hollow shaft of 3 1-2 in. in length. It is machined from type N Vanadium seamless steel tubing with a notch at the middle point of its length which provides against turning in the connecting rod clamp. The wrist pin is hollow to obtain lightness and heat radiating qualities. Before the wrist pin is inserted in the piston, the brass bushings are reamed to .740 in.—.741 in. The wrist pins are then fitted in the piston which they fit most snugly. This work is held to a half thousandth of an inch, for any looseness of piston pin bearings will soon increase in operation developing a knock in the engine. Sufficient tension should be on the wrist pin bearings to almost sustain the weight of the connecting rod when piston is held at an angle. The piston has three grooves around its circumference in which spring rings are fitted. The two rings near the top of the piston are termed the compression rings. Their duty is to prevent the escape of gas between the piston and cylinder wall. The lower ring around the skirt is termed the oil ring. Its duty is to keep excessive qualities of oil from working its way into the Combustion Chamber.

Piston Dimensions.—

Length 3.808 in.—3.817.

Diameter at skirt 3.748 in.—3.749 in.

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Diameter at 2nd ring 3.743 in.—3.745 in.
Diameter at top 3.738 in.—3.740 in.
Ring grooves ¼ in. wide by 13/64 in. deep.
Diameter of piston bushings.740 in.—.741 in.
Diameter of wrist pin .740 in.—.741 in. Length of pin 3 1-2 in.

Before fitting the piston in the cylinder case the bores are carefully wiped out and the crank bearings are guaged. If the crank bearing is slightly undersize, the cap edges may be filed to compensate. No more than .004 nor less than .003 clearance should be allowed between cylinder and skirt of piston, yet the piston must move freely when pushed back and forth in the bore. It may be necessary to file burrs from piston or to tap out a slight distortion of the skirt with a rawhide hammer in order to secure free travel. The piston rings before assembling are guaged and divided into three classes.

1. .003 in. gap when ring is compressed, used as No. 1 or top ring on piston.

2. .005 in. gap when ring is compressed, used as No. 2 or middle ring on the piston.

3. .008 in. gap when ring is compressed, used as No. 3 or bottom ring on the piston. The piston rings are tapered around the circumference, the smaller diameter of the taper being the side marked either with a machined groove, "FORD" in script, or a punch mark. When rings are assembled to the piston these marks should be toward the top of the piston. A tapered ring scrapes the cylinder walls of excess oil. Also the ring will wear quickly to conform with irregularities in the cylinder walls because of the smaller bearing surface. After fitting pistons in cylinders, the cap and corresponding side of the connecting rod shank are notched with a file on the wrist pin clamp bolt side of the rod. Thus "I" for the piston is number one cylinder, "II" for the piston is number two cylinder, etc. This precaution is taken so that caps will be reassembled on

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the same connecting rods and in the same positions as before removing. The .003 in. paper shims between connecting rod shank and cap are removed; thus a tension between babbitt and crank bearing is produced when cap is assembled which provides for the subsequent running in process of the bearings. Piston rings are assembled to pistons and pistons are inserted into the cylinder with the aid of a ring squeezer. See that the gaps in the three rings on each piston are not in line with one another. The gaps should be 120 deg. apart. Connecting rod caps are oiled and assembled on their respective connecting rods, clamping around crank bearings. Bolts are tightened and locked with cotter pins. The engine is now placed on the belting block and run at 700 RPM for about 60 sec. A connecting rod bearing which has been properly "run in" will be very hot after belting and this heat determines whether the bearing will pass inspection or not.

Valve Timing.—One intake and one exhaust valve are located in the combustion chamber of each cylinder in the Ford Engine. The intake valve admits the fresh gas drawn from the carburetor through the inlet manfold, and the exhaust valve, when opened permits the burned gases to be forced out into the exhaust passage. The valves are kept seated by means of coil springs which bear against a cap carried at the lower end of the valve stem. They are alternately opened and closed at the proper time by the cams on the camshaft striking against push rods which in turn push the valves from their seats. The cam is of pear shaped profile, the center of the larger portion or heel coincides with the shaft bearing center. When the heel of the cam is in contact with the push rod a clearance of .022 in.—.032 in. exists between the end of the push rod and the valve stem end which allows the valve spring free action, holding the valve in contact with its seat. As the cam is revolved the raised portion or toe of the cam forces the push rod up, closes this clearance and lifts the valve from its seat.

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The lift of the valves in the Ford Engine is 7-32 in. In the timing of the valve action, the points of opening and closing of the valves with respect to piston movements are considered. The timing of the valve in the Ford Engine depends:

1. On the proper size, shape and positioning of the cams on the shaft. (The cams being integral with the shaft and ground to shape according to master cams on the grinding machines, require no adjustment).

2. On the proper marking of the tooth of the small timing gear fitted to the crankshaft so that the mark "Ford" is 1 deg. and fifteen min. to the left of the center line through keyway, the key being in line with the crankthrows.

3. On the meshing of the timing gears so that the "Ford" tooth of the gear meshes with the space marked "O" of the large gear.

4. On the proper clearance between valve stem end and push rod when the push rod is in contact with the heel of the cam.

The "Timing" operation is an adjustment of the clearance mentioned above and a check on the possible errors in fitting gears by actually checking valve closings and openings with the respect to position of piston as these events take place.

Firing Order.—In order to understand the sequence of operation of the eight valves in the Ford Motor it is necessary to know the firing order of the four cylinders. In order to produce one power stroke the piston must pass through a cycle of four strokes, two up and two down; the sequence being:

1. In take, a down stroke of the piston. 2. Compression, an up stroke. 3. Combustion, a down stroke. 4. Exhaust, an up stroke. The sequence of events in the cycle must be maintained in each separate cylinder and in order that the firing may be regular, one piston must be on the combustion stroke every 180 deg. of crank travel. As stated before, the Ford crankshaft has four throws, the two middle throws point-

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ing in one direction and the two other throws in a direction 180 deg. from this or exactly the opposite direction. If number one piston is on its power stroke, (down stroke of the piston) the piston in the cyinder next to fire should be at the same time on its compression stroke which is an up stroke of piston number two because the opposite direction of its crank throw from that of number one fulfills this condition and starts down on its power stroke as number one piston exhausts. Similarly, because of the opposite direction of its crank throw from that of number two piston number four piston is traveling upon its compression stroke while number two cylinder fires and is next to be forced down by combustion. Number three cylinder is the last of the four to fire as its piston is compressing while number four piston is on its power stroke. The firing order of the Ford engine is, therefore, 1-2-4-3.

The opening and closing of valves with respect to position of pistons are as follows: Exhaust valve opens when the piston reaches 5-16 in. before bottom center the distance from the top of the piston head to the top of the cylinder casting measuring 3 3-8 in. The exhaust valve closes at top center the piston 5-16 in. above the cylinder casting. The intake valve opens 1-16 in. past top center or 1-4 in. from top of cylinder to face of cylinder casting. The intake valve closes 9-16 in. past bottom center,—the distance from the top of the piston to the face of the cylinder casting being 3 1-8 in. (Figs. 3 and 4). The exact point of opening or closure of a valve according to piston movement may be determined by applying a twisting tension to the valve head with the thumb and forefinger while turning the crankshaft slowly over. While the valve is closed, the fingers will be unable to turn the valve head, while at the opening point of the pressure between valve and seat will be relieved and the valve head may be turned easily with the fingers. The point of closure may be found in a similar manner. The

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clearance between valve stem and push rod influences the points of opening and closing of valves. These may be checked, six at a time when the pistons are half through their stroke.

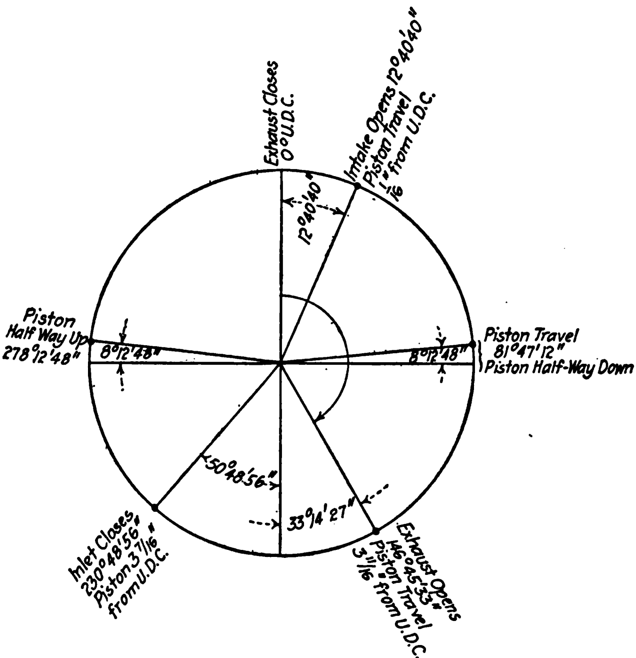

Fig. 3—Ford Valvetiming in Degrees of Crankshaft Rotation

Previous to 1913 slightly different cams were used in the Ford Motor than at present. These cams were not quite so pointed at the toe as those used at present and the exhaust cams were blunter than the intake cams. In changing the camshaft to its present form all of the cams were made identical in profile and symmetrical. This change altered the timing measurements to those given above. Previous to 1913 the rule was as follows:

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Exhaust valve opens 3-8 in. before bottom center 3 5-16 in. from face of cylinder case to top of piston.

Exhaust valve closes 1-64 in. past top center or 19-64 in. from piston to face of case.

Intake valve opens 7-64 in. past top center or 13-64 in. from piston to face of case.

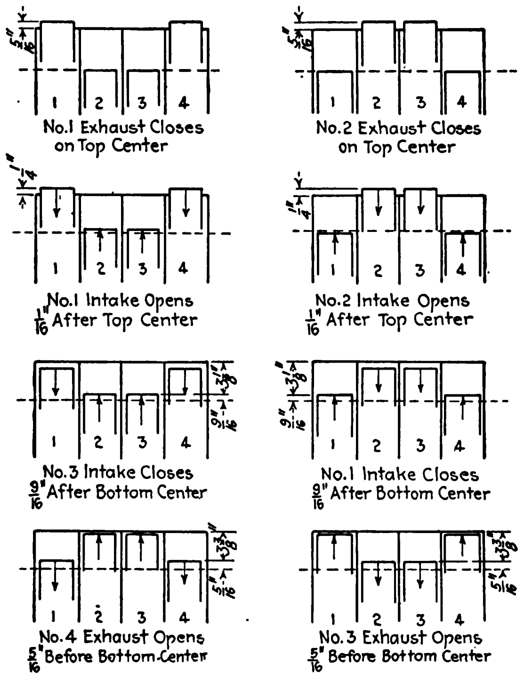

Fig. 4.

Intake valve closes 3-8 in. past bottom center or 3 5-16 in. from face of case to top of piston.

Typical Cycle of Piston in One Cylinder of Ford Engine.— Piston moves from top center down on its intake stroke. The intake valve opens 1-16 in. past top center thus allowing the

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piston opportunity to reduce the pressure in the combustion chamber caused by the previous exhaust stroke before opening the passage to the intake manifold. The piston travels downward drawing the gas mixture from the carburetor into the cylinder. The intake valve is held open until the piston is 9-16 in. travel past bottom center on the next up stroke. This lag of intake closure allows a greater volume of gas to force its way into the cylinder than if the valve were closed at bottom center, due to the great inertia of the gas which travels through the opening at 4,000 to 5,000 ft. per minute. On the succeeding up stroke of the piston the gas is compressed from 40 to 60 lbs. pressure per square inch, both valves of course being closed and the cylinder head gas tight. At or slightly before the top center of this stroke, the charge is fired and the piston is forced downward by the expansion of the gas on its power stroke. 5/16 in. before the bottom center of this downward stroke, the gases have practically exhausted their useful energy and the exhaust valve is opened at that point. On the succeeding upward stroke the exhaust valve is fully opened and the burnt charge is forced out through the exhaust manifold. At the top center of this stroke the exhaust valve is closed and the piston repeats its cycle. It will be understood from the above that each valve must be opened once during one complete cycle or four strokes of its respective piston. In order to produce four piston strokes the crank shaft must revolve twice. Therefore, the cam actuating the valve should revolve once during each revolution of the camshaft. For this reason the camshaft is geared to run at half the crankshaft speed.

Fitting Cylinder Head.—After the timing operation, the two outside pistons are turned to their top center positions, these acting as temporary locating plugs in assembling the cylinder head and gasket. The head is bolted to the case with 7-16 in. x #14 U. S. S. thread bolts, 15 in all. The magneto coil is now bolted to the radius at the rear end of the case. It is

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shimmed so that the distance from the crankshaft flange to a place passing through the faces of the coil is 27-32 in. The oil tube is then inserted and bolted in place.

Hanging Transmission.—The Ford Transmission is built with the flywheel as a unit. This weight added to that of the magnets carried on the flywheel makes possible the use of an unusually light flywheel casting. The distance from the magnet clamp faces to the depression in the center to which the crankshaft flange is bolted should be 13-16 in.—53-64 in. The flywheel and transmission assembly is bolted to the crankshaft flange with four 1 3-16 in. x 20 in. thread cap screws and is located by two pins .468 in. in diameter. The clearance between the faces of magnet clamps and coil core faces should be not less than .027 in. nor more than .040 in. If a smaller clearance than the above is used, there is danger of rubbing or striking between the moving and stationary parts. If more than .040 in. the current output of the magneto is weakened. In hanging the transmission assembly the motor is placed on its side; when it is again turned upright the flywheel will sag slightly making the clearance smaller at the bottom than at the top. For this reason it is usually allowed a larger clearance at the bottom than at the top to compensate for the sagging. The pan, or lower half of the crankcase is bolted to the cylinder case using castellated nuts and cotter keys. The ball cap with end bearings for the transmission shaft is bolted to the pan end. All joints between pan and case are fitted with gaskets. The transmission cover containing the pedal assemblies is bolted to the pan and ball cap. A gasket or packing of felt is provided between all joints. The clutch clevis lever is assembled and pedals adjusted. The manifolds, intake and exhaust, are bolted in position with copper and asbestos, gaskets interposed. Studs 3-8 in. x 24 thread, clamps and nuts are used for this purpose. The magneto contact point is fastened to the transmission cover by three screws and the engine assembly is completed.

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Block Test.—The purpose of the block test is a final test for defects in material and workmanship and a "running in" process to limber up bearings. The block consists of a support for the assembled power plant, and a 20 H. P. motor with suitable universal joint linkage to connect to the engine to be tested. The engine to be tested is hoisted on the block, linked to the power motor and started. While starting the electric motor, the clutch is released in the engine transmission, thus eliminating possibility of overload and blown fuses. The quantity of oil should be gauged by the testing cocks in the lower right side of the pan before the motor is run. The clutch pedal is adjusted by turning adjustable stud on the right hand side of the transmission cover, the water intake and manifold bolts and studs are tightened and manifold joints are tested for leaks by applying oil around the gaskets. Any leaks will be indicated by air bubbles. Inspection is made for radius oil leaks, cracked transmission covers or cylinder cases, loose or missing bolts and nuts, noises indicating noisy timing gears, pistons striking head, magnet clamps rubbing on coil, clutch shift rubbing on drive shaft, metal objects, nuts, etc., in transmission or crankcase; crankshaft rubbing on gear or crankcase, leaky valves.

The S. A. E. Horse Power Formula.—The horse power of a gasoline engine is dependent upon the following things; number of cylinders, area of piston heads, average number of pounds per square inch exerted upon the piston during the working strokes, and the revolution per minute of the engine.

It has been worked out upon the assumption that the piston speed is 1,000 ft. per minute and that the mean effective pressure is 90 lbs. per square in. Inasmuch as the piston speeds of modern engines run up as high as 2,000 to 3,000 ft. per minute and the mean effective pressures per square inch go up to 110 lbs. to 120 lbs. you can see that this formula is far from accurate. In some cases it gives a rating which is only about one

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third of the actual horse power development of the engine.

Piston Speed.—The piston speed is supposed to be at 1,000 ft. of piston travel per minute. The shorter the crank the quicker it can be turned; the longer the crank, the more piston travel per stroke. Therefore the piston can travel slower and still travel the required distance.

An Example.—Suppose the stroke of an engine is 4 in. It would have to make three strokes to travel 12 in. because each stroke is 4 in. in length. Take on the other hand an engine with a stroke of 6 in. It would have but two strokes to make per 12 in. Therefore, it is evident that the shorter the stroke the faster it must move to travel the 1,000 ft. in the specified time.

How to figure to the S. A. E. formula:

$$\text{H. P.} — \frac{D^2\ N}{2.5}$$

D^2 (diameter square) 3 3-4 x 3 3-4—14 1-16
N (number of cylinders) 14 1-16 x 4—56 1-4
2.5 (divided by 2.5) 56 1-4 ÷ 2.5—22 1-2

Meaning of Horse Power.—Horse power nowadays has nothing to do whatever with the power developed by a horse, but is an unscientific way of defining power. A motor rated at one horse power is capable of doing one mechanical unit of work, which is equal to the power expended in lifting a weight of 33,000 lbs. through a height of one foot in one minute of time.

The French horse power equals 32,549 feet pounds and is thus less than the English.

Meaning of "Brake" Horse Power.—(B. H. P.) Brake Horse power is the power available at the driving shaft of the engine, such as could be determined by making a power absorption test by means of a brake type of dynamometer.

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Meaning of "Actual" Horse Power.—Actual horse power is the amount that would be available if there were none absorbed by friction within the engine itself, and the total energy of the explosion was transmitted without friction or other losses to the shaft.

Meaning of Indicated Horse Power.—(I. H. P.) Indicated horse power is measured by taking an indicator diagram, which shows the "mean effective pressure" of the explosion in pounds per square inch.

For high speed engines an optical device is used which plots out the pressure line on a photographic plate. From this the "mean effective pressure" during the stroke can be calculated.

Total horse power of an engine is the same as its indicated horse power.

If an engine develops on brake tests, seven brake horse power and it takes three horse power to drive itself it is therefore properly called a ten indicated and seven actual or brake horse power engine.

Bore		Horse Power			
Inches	Millimeters	1 Cyl.	2 Cyl.	4 Cyl.	6 Cyl.
2½	64	2.5	5.0	10.0	15.0
2⅝	68	2.8	5.5	11.0	16.5
2¾	70	3.0	6.0	12.0	18.1
2⅞	73	3.3	6.6	13.2	19.8
3	76	3.6	7.2	14.4	21.6
3⅛	79	3.9	7.8	15.6	23.4
3¼	83	4.2	8.4	16.9	25.3
3⅜	85	4.6	9.1	18.2	27.3
3½	89	4.9	9.8	19.6	29.4
3⅝	92	5.3	10.5	21.0	31.5
3¾	95	5.6	11.2	22.5	33.7
3⅞	99	6.0	12.0	24.0	36.0
4	102	6.4	12.8	25.6	38.4
4⅛	105	6.8	13.6	27.2	40.8
4¼	108	7.2	14.4	28.9	43.3
4⅜	111	7.7	15.3	30.6	45.9

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Bore		Horse Power			
Inches	Millimeters	1 Cyl.	2 Cyl.	4 Cyl.	6 Cyl.
4½	114	8.1	16.2	32.4	48.6
4⅝	118	8.6	17.1	34.2	51.4
4¾	121	9.0	18.0	36.1	54.2
4⅞	124	9.5	19.0	38.0	57.0
5	127	10.0	20.0	40.0	60.0
5⅛	130	10.5	20.5	42.0	63.0
5¼	133	11.0	22.0	44.1	66.1
5⅜	137	11.6	23.1	46.2	69.3
5½	140	12.1	24.2	48.4	72.6
5⅝	143	12.7	25.3	50.6	75.9
5¾	146	13.2	26.4	52.9	79.3
5⅞	149	13.8	27.6	55.2	82.8
6	152	14.4	28.8	57.6	86.4

Ford Model "T" Engine Repairs.—

1. Disassemble and clean all parts.

2. Inspect main bearings to see that they are not worn egg-shaped.

3. File raised babbitt on top of crankshaft bearings flush with top and at 25 deg. angle from edge of cylinder to center.

4. Try crankshaft in bearings and note end play. Fit new main bearings, .003 in. to .006 in. overhaul .003 in. to .006 in. Watch and allow for surplus thrust when gauging gap.

5. Examine to see that main bearing caps have good bearings.

6. Note how many brass liners were under caps. Remove one and tighten cap as much as possible without stripping threads. Test for tightness. If perfectly fitted crankshaft can be turned over by hand. Next adjust center and front bearings making sure to get the same tension on each. When the three bearings are properly fitted you will be able to turn crankshaft around with both hands.

7. Note condition of pistons. If not scored badly file high spots from same.

8. Inspect pin to make sure it is not too loose in the bushings. High limit .0002 in. play. Also see that pin does not project sidewise beyond side of pistons. Piston rings fitted with

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.0001 in. side play in grooves. Upper ring fitted with gap of .003 in. between ends; center ring .005 in.; lower ring .010 in. to .015 in. If pistons are O. K. begin to fit them in cylinders. When newly fitted, pistons are loose on .003 in. and tight on .004 in. For overhaul job clearance may be .004 to .006.

9. After pistons are properly fitted note whether connecting rods are loose on pin bearings of crankshaft. If so file .002 from face of cap. Tighten rod to pin bearing. If O. K. finish other rods in same manner.

10. See that valve seats show complete circle of bearing. If not, recut or if not bad when valves are being assembled a little grinding will give desired results.

11. When valves are O. K. note tension of springs (18 to 22 lbs.) If O. K. assemble.

12. Time motor. You will find small gap on used cars. Grind end of valves to proper length allowing .020 gap.

13. When motor has been properly timed, install cylinder head and gasket on cylinder.

14. Place camshaft in motor, when front and center cam bearing have been inspected to make sure that they are not too badly worn. (High limit .002 in. play). Make sure that larger time gear is not badly worn or burred.

15. When cam shaft and gears are assembled see that same have from .002 in. to .005 in. back lash or space between teeth, (New job .002 in. to .004 in.).

16. Examine magnets on transmission. See that same are parallel and free from all metal or dirt.

17. Examine all connections and coils on magneto assembly and make sure that all are in good condition. Shim and fasten same to cylinder.

Special note: Allow for excess end play of crank at main bearing. Also due to nonsupport of coil at bottom half allow .010 in. more at contact half and .030 in. at bottom half.

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18. Place transmission on crank and see that four bolts are tight. Gap space between magnets and coil assembly by turning transmission cover and crankcase at four positions.

19. Place pulley on crankshaft.

20. Before placing motor on crankcase, see that same is clean and free from any loose metals. Also that felt gaskets are flat and ample at front wall recess.

21. If inspection of transmission cover parts shows them in good condition, place cover on motor. When assembled, try ball cap for alignment. Same should fit squarely to transmission cover and crankcase at four positions.

22. To set transmission cover connection properly ascertain amount of play in slow speed notches and adjust connection when pedal is set at 1-2 of play of cams.

23. In assembling parts be certain that the following are properly oiled; valve stems, crankshaft bearings, push rods, piston pin, connecting rods and caps, commutator roller, ball cap, and clutch shaft. (This is very important).

24. See that there is a clearance of 1-32 in. between piston pin bushing and connecting rod when tapped on one side of bearing on crankshaft.

Questions and Answers on the Ford Model T Engine

Q. What is the principle of a gasoline motor?

A. Gasoline when mixed with air and compressed is highly combustible. An explosion is a violent expansion caused by rapid combustion of confined gases. In the gasoline engine the mixture is drawn into a cylinder where it is compressed by an advancing piston, and then ignited by an electric spark which sends the piston downward and through the connecting rod imparts a rotary motion to the crankshaft.

Q. What type engine is the Ford?

A. Four cylinder "L" head type.

Q. What is meant by the term cycle as applied to a gasoline engine? By 4 cycle?

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A. The term cycle as applied to a gasoline engine refers to the four cycle evolutions of intake, compression, power and exhaust for each piston.

Q. How many explosions does it require to run a crankshaft over one revolution in a four cylinder, four stroke cycle engine?

A. Two explosions are necessary.

Q. Name the important parts of the Ford engine.

A. Crankshaft, camshaft, piston assembly, connecting rods, valves, pushrods, flywheel and cylinders.

Q. What is the purpose of the valves?

A. There are eight valves in the Ford engine, two for each cylinder; one intake and one exhaust. The intake valve admits fresh gas drawn from the carburetor through the inlet pipe. The exhaust valve permits the burnt gas to be driven out through the exhaust pipe to the muffler. The valves are alternately opened and closed by the cams on the camshaft striking against the pushrods which lift the valves from their seats.

Q. What is the purpose of the pistons?

A. On the downward stroke the suction of the piston draws the fresh gas from the carburetor through the inlet pipe and valve into the cylinder. The upward movement of the piston compresses the gas into a very small space between the top of the piston and the depression in the cylinder head known as the combustion chamber. The compressed gases exert a pressure of approximately 60 lbs. per square inch. At this point an electric spark generated by the ignition system explodes the gases, drives the piston downward, thus producing the power which turns the crankshaft. On the next stroke upward the piston drives the burned gas out through the exhaust valve and pipe to muffler.

Q. What is the purpose of the connecting rods?

A. To connect pistons and crankshaft. The small end of the rod is fastened to the piston pin by means of a set screw and cotter pin. The opposite or bearing end is fastened to the crankshaft and is the medium through which the reciprocating motion of the piston is conveyed to the crankshaft where it becomes a rotary motion.

Q. What is the purpose of the crankshaft?

A. To convert the reciprocating motion of the pistons and connecting rods into a rotary motion.

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Q. What is the purpose of the piston rings?

A. To make the cylinders air tight, oil tight, and create compression, so that when the intake valve opens and the charge of gas rushes into the cylinder, none of it will escape between the pistons and cylinder walls.

Q. What is the purpose of the flywheel?

A. To give the engine momentum and to cover the intervals of time when no power is being applied to crankshaft by pistons.

Q. How are Ford valve seats cut?

A. They are cut convex.

Q. What is the advantage of a convex valve seat?

A. The advantage of a convex seat is that the valve has a tendency to pound itself into the seat and thereby prevent leaks.

Q. How many steam holes in top of case and in cylinder head? What are they for?

A. There are five steam holes in case and five in cylinder head to prevent the steam from gathering in pockets and stopping circulation of water.

Q. State number of bolts and the size; also thread for cylinder head bolts.

A. 15 bolts $\frac{7}{16}$ in. x $2\frac{9}{16}$ in.

Q. How many pounds pressure has the valve spring when in place with valve closed?

A. 20 lbs. pressure.

Q. Why is it necessary to have a radius on crankshaft bearing?

A. Radius on crankshaft bearings is to give added strength.

Q. How is the crankshaft hung after case leaves boring operation?

A. File off edge of bearings on cylinder case to 40 deg. angle, punch oil holes and place crankshaft—see that it revolves freely and allow .002 in. to .004 in. end play, place bearing caps on and rock, build up space between caps and cylinder case with shims replace bolts and nuts and tighten and secure with cotter pins, then burn in bearings on burning in stand.

Q. How much end play should crankshaft have when fitted in cylinder case?

A. .002 in. to .004 in. end play. Less, if movement is free.

Q. Why does not the front and center main bearing cap cover the entire crankshaft bearing as the rear main bearing cap does?

A. The front and center main bearing caps do not cover the entire bearing because of two reasons, i. e. to allow lubrication and for

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expansion. It is necessary to have the rear main bearing cap fit tight to prevent lengthwise expansion when engine heats up. If it had any play it would cause the gap between the magneto and coil spools to widen, thereby lessening the output of the magneto.

Q. What effect would an unbalanced crankshaft have upon the motor?

A. It would throw the whole motor out of balance and create vibration.

Q. What is the duty of a camshaft?

A. To regulate the opening and closing of the intake and exhaust valves at correct intervals.

Q. Give directions for putting large time gear on camshaft.

A. Put large time gear on camshaft with zero marks opposite number one cam, line up dowel pin holes and drive in dowel pins, screw on lock nut making sure that same is tight and the gear is pulled firmly in place.

Q. Suppose large time gear was set so time mark was with the first cam instead of opposite. Would it affect the firing of the motor?

A. No.

Q. How would you mark the large time gear and small time gear to mesh them together in proper position if there were no marks on them?

A. Place scale across dowel pin hole center and mark to the left on top, skipping two teeth and mark on third.

Q. Give directions for properly inserting camshaft and gear.

A. Drive center bearing in case and line up set screw holes in front bearing and case, guide rear bearing into bushing, then line up center bearing and drive in far enough to allow correct meshing of time marks, making sure that teeth will not strike on large and small gear, then drive flush with gear case, line up set screw holes and put in set screws, try gears for back lash allowing .002 in. to .004 in.

Q. What is the purpose of the recess at rear end of front bearing?

A. To allow clearance for number one pushrod.

Q. What should be the micrometer distance outside to outside from crankshaft bearing to camshaft bearing?

A. Distance on an O. K. motor is 5,220 in. hot and 5,218 in. cold allowing .002 in. oversize and .003 in. undersize.

Q. Why are the pistons made of cast iron?

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A. Because they more readily radiate heat and also because they are less expensive.

Q. What allowance is made in fitting pistons in cylinders in new motor? Overhauling motor? Rebored cylinders?

A. Fitting pistons in cylinders in a new motor, .004 in.; overhauling motor .006 in.; rebored cylinders .004 in.

Q. Why should pistons all be equal height?

A. Pistons should be of equal height so that compression will be equal.

Q. To what height should pistons rise above face of cylinder case? What allowance permitted?

A. They should rise $\frac{1}{16}$ in. above face of cylinder case and .010 in. over or under.

Q. Why is the top of a piston beveled?

A. To eliminate weight without sacrificing strength.

Q. Why is piston diameter smaller at the top than at bottom?

A. To allow for expansion.

Q. Why is the piston made as long as possible?

A. To secure the greatest bearing surface possible.

Q. Why is the wrist pin hollow?

A. It is lighter and a hollow piece is the strongest section known to mechanics.

Q. Which way does the cylinder bore wear the most?

A. Valve side.

Q. Give the rule for figuring piston speed travel in feet per minute.

A. Piston speed in feet per minute is found by the formula: twice length of stroke in inches, times number of crankshaft revolutions per minute, divided by 12.

Q. Figure piston displacement of Ford engine.

A. Piston displacement is found by the formula: diameter of bore squared, times .7854, times length of stroke, times number of cylinders.

Q. Why is a piston ring necessary near the bottom of the piston?

A. To allow for lubrication and to prevent piston slap and to insure a more even wear.

Q. How much gap should be allowed in fitting piston rings? How should rings be placed on piston?

A. .003 in. to .005 in. on two top rings and .008 in. on oil rings. Rings should be placed on piston with machined groove upwards.

Q. What is the length of connecting rod, from center to center of bearings; the width of connecting rod bearings?

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A. Length 7.025 in.—width 1.248 in.

Q. How can you determine proper fitting of new wrist pin?

A. By holding piston at an angle and letting rod fall from side to side of piston. The weight of rod should carry it over slowly.

Q. How should caps be placed on connecting rods in fastening them to crankshaft bearings?

A. All file marks on the valve side of motor.

Q. How can you determine whether connecting rod bearings are properly tightened?

A. By tapping with a hammer.

Q. What is the firing order of the Ford motor and why so?

A. Firing order is 1, 2, 4, 3; to reduce vibration.

Q. What is the reason for timing the operation of the valves?

A. So that they will open and close at the correct intervals.

Q. How are the valves timed?

A. Gap between pushrods and valve stems should be adjusted; .022 in. to .032 in. gap is allowed. When No. 1 piston is on top center exhaust valve should be closed, when it starts downward and travels $\frac{1}{16}$ in. intake valve should open and remain open until the piston is $\frac{9}{16}$ in. past bottom center. Exhaust valve opens $\frac{5}{16}$ in. before bottom center and closes on top center.

Q. How can you determine the point at which a valve opens or closes? What is top center? Bottom center?

A. Intake valve should open $\frac{1}{16}$ inch past top center or when piston is ¼ in. from face of motor, should close $\frac{9}{16}$ in. past bottom center or when piston is 3⅛ in. from face of motor. Exhaust valve should open $\frac{5}{16}$ in. before bottom center or when piston is 3⅜ in. from face of motor, and should close on top center. Top center is when piston is at its highest point of travel.

Q. What is piston travel during exhaust stroke, during intake stroke?

A. Piston travels upward during exhaust stroke and downward during intake stroke.

Q. What is the reason for opening exhaust valve $\frac{5}{16}$ in. before bottom center?

A. Because the power stroke has spent its strength by the time piston reaches that point.

Q. What is the difference between 1912 camshaft and those now used?

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A. 1912 camshafts had a rounder point on the cams and motors were timed differently.

Q. What is the purpose of the transmission?

A. To enable the car to be driven at different speeds forward and in reverse and to disconnect engine from the load.

Q. What is a planetary transmission?

A. The Ford transmission is a planetary transmission. This type is light, compact and especially adapted for use with a unit power plant. The action of its gears is similar to the action of the planets, they rotate on their own axis and at the same time revolve about the central gears. Therefore, it is called a planetary transmission.

Q. Why is a clutch necessary on an automobile.

A. A clutch is a mechanical device used to connect and disconnect two moving parts of a machine at the will of the operator. In an automobile it allows the motor to run independent of the motion of the car.

Q. What type of clutch is used in Ford Motors? How is it assembled?

A. Ford motor has multiple disc clutch. In the Ford car the parts connected by the clutch are the transmission shaft (which is fastened to the flywheel and to the crankshaft by cap screws and dowel pins) and the brake drum (which is connected to the drive shaft by means of the drive plate and universal joint). A grooved drum is keyed to the rear end of the transmission shaft. Twelve flat hardened steel discs are slipped over this drum, lugs in the inner circumference of the discs fitting into the grooves on the outer surface of the drum, acting as keys to cause the discs and clutch drum to turn together. Thirteen larger flat steel discs alternate with the small ones; these have notches on the outer circumference fitting over lugs on the inner surface of the brake drum, acting as keys to cause the large discs and brake drum to turn together. The first and last discs are large ones to prevent the small ones from slipping out of place. A clutch push ring bears against the rear disc. This ring has three lugs projecting back through holes in the drive plate. Pressure is brought upon these lugs by three clutch fingers adjusting screws, threaded through three clutch fingers hinged at the outer edge of the drive plate. The inner ends of the clutch fingers bear against the front end

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of the clutch shift collar. Pressure is applied to the rear end of this collar by means of a heavy coil spring supported by a cup shaped spring support pinned to the drive plate sleeve.

Q. What is the tension of the clutch spring.

A. 90 lbs.

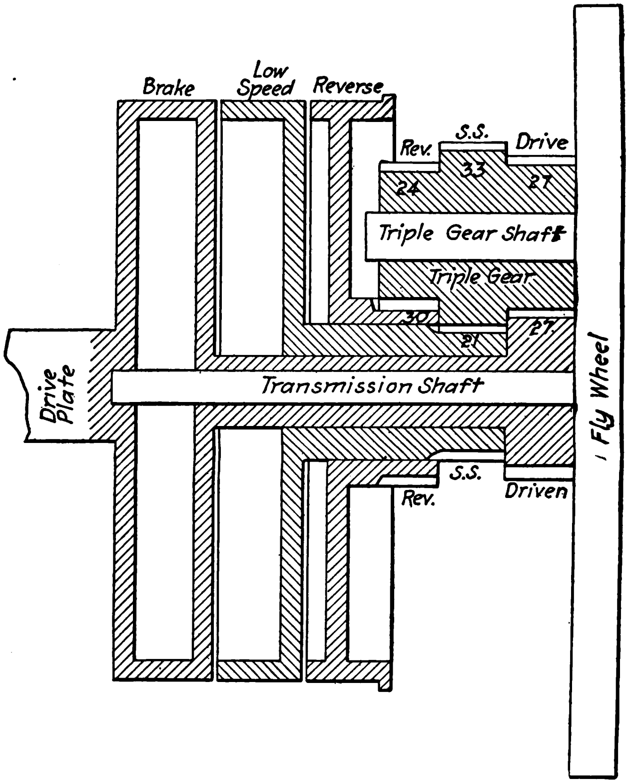

Fig. 5.

Q. How is it adjusted to secure proper tension?

A. By means of the three adjusting screws in the clutch fingers.

Q. What pressure does the clutch spring impart to the clutch disc through the leverage of the clutch fingers?

A. 324 lbs.

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Q. What is the chief advantage of the multiple disc clutch over other types?

A. More friction surface.

Q. How are the drums and gears assembled?

A. To understand the action of the transmission in slow speed and in reverse it is necessary to know its construction. The brake drum is fastened to the end of a long sleeve which revolves freely upon the transmission shaft. Then we have the slow speed drum fastened to a shorter sleeve which slips over the brake drum sleeve and turns freely upon it. The front end of the slow speed drum sleeve has 21 teeth cut into its surface forming the central slow speed gear. The reverse drum is fastened to a still shorter sleeve which forms the central reverse gear, having 30 teeth on its outer surface. This revolves freely upon the slow speed drum sleeve. Each sleeve is bushed to fit the next sleeve. Each drum and sleeve turns independently and the brake drum sleeve turns freely on the transmission shaft. A 27-tooth spur gear is keyed on to the front end of the brake drum sleeve just ahead of the slow speed gear. This is the driven gear and turns with the brake drum and consequently with the drive shaft. When the clutch is free the speed of the car depends upon the speed of this gear. Mounted upon three pins into the web of the flywheel 120 deg. apart are three sets of planetary spur gears, each set having three gears. The drive gear has 27 teeth and meshes with the 27-tooth central driven gear. The next gear has 33 teeth and meshes with the 21-tooth central slow speed gear. The rear one has 24 teeth and meshes with the 30-tooth central reverse gear.

Q. What is neutral? Explain how neutral is secured in the Ford transmission.

A. When the power is disconnected from the drive shaft and engine is running independently. By releasing pressure on discs.

Q. How is high speed or direct drive secured in Ford transmission?

A. By releasing the pressure of the clutch spring on the clutch shift and allowing the clutch spring to exert its full pressure on the three set screws in the clutch fingers which push against the disc in the brake drum.

Q. How does the brake act in the Ford transmission?

A. When service brake is to be used, put car in neutral and

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press on brake pedal. The brake band is then tightened around the brake drum.

Q. Explain action of transmission gears in reversing the car.

A. The reverse drum is held stationary by a band around it. The 30-tooth central reverse gear being riveted to the reverse drum is also held stationary. The 24-tooth planetary reverse gear rolls around the 30-tooth gear being pulled by the pin in the flywheel. In going around the 30-tooth gear once (one turn of the flywheel) the 24-tooth gear makes 30/24 or 1¼ revolutions to the left on its pin. The drive gear being riveted to the 24-tooth gear, also makes 1¼ revolutions to the left on the pin. The excess ¼ revolution of the drive gear (to the left) will turn the driven gear ¼ turn to the right for one revolution of the flywheel or one turn to the right for four turns of the flywheel giving a gear ratio of 4 to 1 in reverse.

Q. Explain the action of the transmission gears in slow speed.

A. The slow speed drum is held stationary by a band thus holding the 21-tooth central gear stationary. The 33-tooth planeary slow speed gear is pulled around the 21-tooth gear making 21-33 revolutions to the left on its pin causing the drive gear to make 12-33 revolutions to the left. The drive gear must turn one whole revolution to avoid turning the driven gear, therefore, the driven gear will be dragged the difference between 21-33 and 33-33 which is 12-33 revolutions to the left (ahead) and for one turn of the flywheel, giving a ratio of 2¾ to 1 in slow speed.

Q. How many turns of motor are required to turn rear wheels once?

A. Ten revolutions of motor to one of rear wheels in slow speed. 14 6-11 revolutions of motor to one of rear wheels in reverse. 3 7-11 revolutions of motor to one of rear wheels in direct drive.

Q. Why is the flywheel necessary?

A. To give the engine momentum and to equalize the power on the piston head produced by the combustion of the gas in the combustion chamber and also to carry the movement of the crankshaft through the period when no power is applied.

Q. Why is a Ford flywheel so much lighter than usual in other motors?

A. Because of the added weight of the transmission it is not necessary to have as heavy a flywheel.

Q. How is a flywheel balanced?

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A. By drilling a sufficient number of holes in its surface and taking away weight from the heavy side of the casting.

Q. What would be the result of an unbalanced flywheel?

A. The result would be excess vibration.

Q. Of what does the Ford magneto consist?

A. Magneto coil support—16 coils—16 magnets—16 cap screws—16 clamps—16 magnet supports (brass and aluminum) 16 screws (brass.)

Q. Why are the outside ends of magnets held in place by brass screws and brass supports?

A. Because they are non-conductors of magnetism.

Q. Why is it important that the magnets be put on the flywheel in the same order that they come in the boxes?

A. Because the poles of the same polarity are placed together always.

Q. What gap is allowable between coil spools and magnet clamps when transmission is hung in place?

A. .025 in. to .040 in. gap.

Q. Where may pistons be filed when fitting new pistons in repair shop?

A. From the bottom up to the bottom ring.

Q. How many size valve stems do we use in repair work?

A. 3 sizes; standard 1-64 in. long and 1-64 larger in diameter.

Q. How many different size pistons do we use in repair work?

A. Three. Standard .0025 and .03125 oversize; .033.

Q. How many different size piston rings do we use in repair work?

A. Two. Standard and .031 oversize.

Q. How many size camshaft bearings do we use for repair work?

A. Standard only.

Q. What is the rated horsepower of the Ford motor?

A. 22.5

Q. What is the common method of figuring the horsepower of a gasoline motor?

A. $$\text{Horsepower}—\frac{(\text{diam. of piston in inches})^2 \times \text{number of cylinders.}}{2.5}$$

Q. To what pressure is the gas compressed in the cylinder head combustion chamber when piston is at top center?

A. 60 lbs. per square inch.

Q. What kind of an oil system has the Ford motor?

A. Splash system.

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Q. What is the amount of oil in crankcase?
A. One gallon.
Q. What kind of oil should be used in Ford motor?
A. A good grade of light oil.
Q. Should graphite be used as a lubricant in motor or transmission and why?
A. Graphite should not be used because it tends to short circuit.
Q. What cooling system has the Ford motor?
A. Thermo-siphon.
Q. What causes the circulation?
A. It is upon the theory that hot water rises to the top therefore when the water in the engine heats it rises to the top and passes through the outlet connection into the radiator where it is cooled and passes down to the inlet connection and back into the engine again.
Q. How much water does the system hold?
A. Three gallons.
Q. What is the purpose of a hot air pipe leading to the carburetor?
A. To help vaporize the gas before it goes into the cylinder.
Q. What would be the result if a leaky joint existed between carburetor and intake pipe or intake pipe and engine?
A. Engine would not start because the suction of the piston would draw too much air and not enough gas.

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CHAPTER III

THE TRANSMISSION AND CLUTCH.

Location.—In the Ford car we have what is known as unit power plant construction that is, the transmission built into the engine. In other cars we have the transmission located just back of the engine, or midway between engine and rear axle and on the rear axle.

Purpose.—To transmit the power from the engine to the drive shaft, to permit change of speed through change gears, to reverse the direction of driving the car, and to allow the engine to gain momentum before applying the load.

Types, Planetary.—This type is one in which the speed changes are brought about by bringing different gears into action, and holding parts of the mechanism stationary. By Planetary gear set, we mean one in which the gears which compose the set turn not only about their own axis, but also about some other axis, such as the central gears. This is the type of transmission used on the Ford car. This type is light, compact and especially adapted for use with a unit power plant. Another advantage is that all gears are in mesh constantly, lessening chances for stripping the teeth.

Sliding Gear.—There are two types of sliding gear sets namely, the progressive and selective. The progressive type is not used very much, as in this type of gear it is necessary to shift through each successive step in order to go from low to high. The selective type is the one used on most cars and trucks at the present time. In this type it is possible to shift from any speed to any other speed, without going through the inter-

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mediate changes. It is built up in two, three and four speeds forward and one reverse.

Sliding Friction.—Transmits power by means of a drive plate fastened to the drive wheel. The driven wheel rests against this and may be moved from one part of the plate to another, thereby obtaining different speeds. Passing to other side of center it receives the reverse.

The Clutch.—A clutch is a device which is used to connect or disconnect two movable parts of a machine at the will of the operator. In an automobile the clutch permits the engine to run independent of the motion of the car.

Types: Cone Clutch.—Multiple disc clutch either of the wet or dry type. The Ford clutch is the multiple disc type running in oil. In the Ford car the parts connected by the clutch are the transmission shaft (which is fastened to the flywheel and to the crankshaft by cap screws and dowel pins) and the brake drum which is connected to the drive shaft by means of the drive plate and universal joint. The small disc drum which is grooved, is keyed to the rear end of the transmission shaft. Twelve flat hardened steel discs are slipped over this drum, lugs in the inner circumference of the discs fitting into the grooves on the outer surface of the drum. These act as keys to cause the discs and clutch to turn together. Thirteen larger flat steel discs alternate with the smaller ones. These have notches on their outer circumference fitting over lugs on the inner surface of the brake drum causing them to turn together. The first and last discs are large ones to prevent the small ones from slipping out of place.

A Clutch Push Ring bears against the rear disc. This ring has three lugs projecting back through holes in the drive plate. Pressure is brought upon these lugs by three clutch finger adjusting screws, threaded through the three clutch fingers, hinged at the outer edge of the drive plate. The inner ends of the clutch fingers bear against the front end of the clutch shift collar. Pressure is applied to the rear end of this collar by

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means of a heavy coil spring, held in place by a cup-shaped spring support pinned to the drive plate sleeve. The spring exerts a pressure of 90 lbs. The clutch finger, acting as a second class lever raises the pressure on the push ring to 324 lbs.; *i. e.* from tips of finger to hinge, 2 1-4 in; from center of pin to hinge 5-8 in. 2 1-4 divided by 5-8 equals 3 3-5 in x 90 equals 324 lbs. The multiple disc clutch is small and compact and has metal to metal friction and revolves in an oil bath assuring its constant lubrication. This enables the discs to come into engagement gradually without shock to the mechanism, because the intervening film of oil must first be squeezed out from between the discs so that engagement is not immediately positive.

Construction of Ford Transmission.—To understand the action of the transmission in slow speed and in reverse it is first necessary to know its construction. First we have the brake drum (previously mentioned as being the driven part of the clutch assembly). This drum is fastened on to the end of a long sleeve, called the brake drum sleeve which revolves freely upon the transmission shaft. Then we have the slow speed drum riveted to a shorter sleeve, which slips over the brake drum sleeve and turns freely upon it. The front end of the slow speed drum sleeve has 21 teeth cut in its outer circumference forming the central slow speed gear. The third drum or reverse drum is riveted to a still shorter sleeve, with 30 teeth cut on its outer surface, which forms the central reverse gear. This revolves freely upon the slow speed drum sleeve. Each sleeve is bushed to fit the next sleeve. Each drum and sleeve turns independently, and the brake drum sleeve turns freely on the transmission shaft. A 27-tooth spur gear is keyed on to the front end of the brake drum sleeve, just ahead of the slow speed gear. This is the driven gear and turns with the brake drum and consequently with the drive shaft. When the clutch is not engaged the speed of the car depends upon the speed of this gear. Mounted on three pins pressed into the web

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of the flywheel 120 deg. apart, are three sets of planetary spur gears, each set having three gears riveted together. The drive gear next to the flywheel, has 27 teeth and meshes with the 27-tooth central driven gear. The next gear (slow speed triple gear) has 33 teeth and meshes with the 21-tooth central slow speed gear. The rear one (reverse triple gear) has 24 teeth and meshes with the 30-tooth central reverse gear.

Action of Gears on Slow Speed.—In explaining the action of the gears, we will consider only one set of triple gears. The other two sets do the same work and serve to balance the weight and to lessen any tendency for the central gears and planetary gears to separate due to worn bushings. They also reduce the wear on any one set and consequently cause quiet action of the gears.

When slow speed is wanted, push the clutch pedal forward from neutral position, while the engine is running. This tightens the band on the slow speed drum, and holds that drum stationary, together with the 21-tooth slow speed gear riveted to it. You hold the 21-tooth gear stationary and the 33-tooth triple gear meshed with it is revolved around the 21-tooth gear by the moving flywheel. In one revolution of the flywheel, the 33-tooth gear will run once around the 21-tooth gear. This will cause the 33-tooth gear to turn on its axis only 21-33 of a revolution, with 12-33 of a turn lost by the drive gear riveted to the slow speed gear. And every 12-33 of a turn the drive gear loses, the driven gear meshed with it gains 12-33 of a turn, since the driven gear and the drive gear on triple meshed into it are the same size (27 teeth), therefore, in one turn of the engine the driven gear is turned ahead 12-33 of a turn when the slow speed drum is held stationary by pressing the slow speed pedal forward. To turn the driven gear one complete turn forward or 33-33 of a turn will take as many revolutions of engine as 12-33 is contained in 33-33 or 33 divided by 12 which equals 2 3-4 turns. Thus 2 3-4 turns of the engine will produce

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one forward revolution of the drive plate attached to the driven gear assembly. (See Fig. 6)

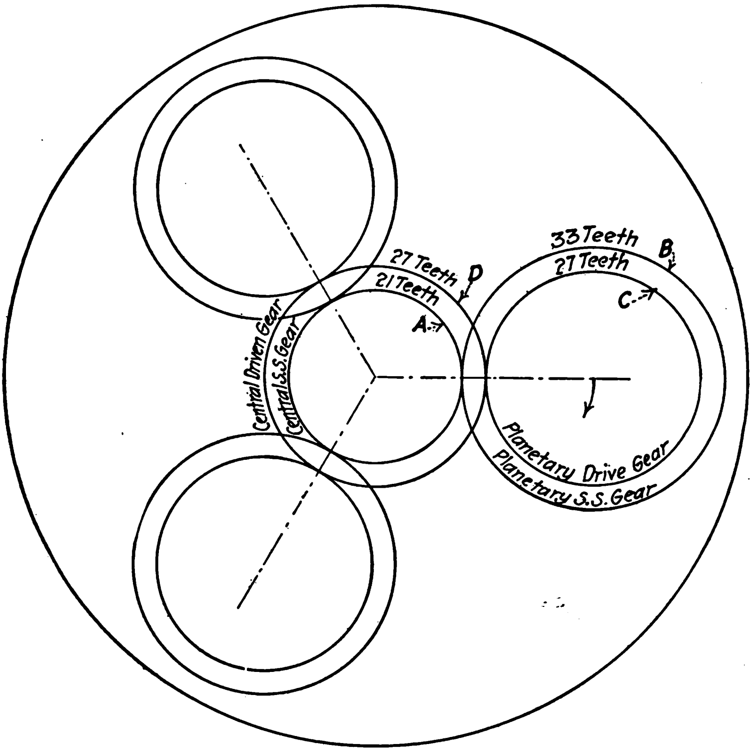

Fig. 6—Action of Gears In Low Speed

Action of Gears in Reverse.—When reverse is wanted, with the engine running in neutral and the car at a standstill, press the reverse pedal forward. This tightens the band on the reverse drum, and holds that drum stationary also holding the reverse gear attached to it stationary. This central reverse gear has 30 teeth. The triple gear meshed with it has 24 teeth. These

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are the only two gears whose action is considered in reversing the car. In one revolution of the flywheel, the 24-tooth triple gear will make one revolution around the 30-tooth gear held stationary. When the 24-tooth gear completes a revolution, around the 30-tooth gear held stationary, it travels 30 teeth which is a gain of 6 teeth on the 24 teeth of the triple gear. 6 teeth in 24 is 1-4 of a revolution gain for that 24-tooth gear, and since the three gears of the triple are riveted together, it is 1-4 of a revolution gain for the 27-tooth drive gear of the triple assembly. The driven gear of 27 teeth meshed with the 27-tooth drive gear will be driven back just as much as the drive gear gains since they are the same size. Therefore, the driven gear will be turned back one quarter of a revolution in one revolution of the flywheel. To turn the driven gear back one revolution, the flywheel must be turned four times. Every four revolutions of the engine, when reverse drum is held stationary produces one backward revolution of the driven gear, brake drum and drive plate since they are keyed together. (See Fig. 7)

Path of Power.—The path of power in high speed is from crankshaft to transmission shaft, small disc drum, small discs, large discs, brake drum, drive plate and sleeve, universal joint, to drive shaft. This is the only time the clutch is engaged. No gears are in use on high speed, the drive being direct, with the transmission revolving as a unit.

In slow speed the power is transmitted through planetary gear pin on the flywheel, slow speed planetary gear, slow speed drum gear, planetary drive gear and the driven gear which is keyed to the brake drum sleeve, drive plate and sleeve, universal joint, to drive shaft.

In reverse the course of power is just the same except that we use the planetary reverse gear and reverse drum gear instead of the slow speed gears.

Ratio of Engine to Rear Axle.—The ring gear has 40 teeth and the drive shaft pinion has 11 teeth therefore the drive shaft

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makes 3 7-11 turns to the rear axle one going straight ahead on high speed. In low speed the ratio of engine speed to rear axle is 10 to 1. In reverse 14.54 to 1. These results are obtained by multiplying the transmission ratio by 3 7-11.

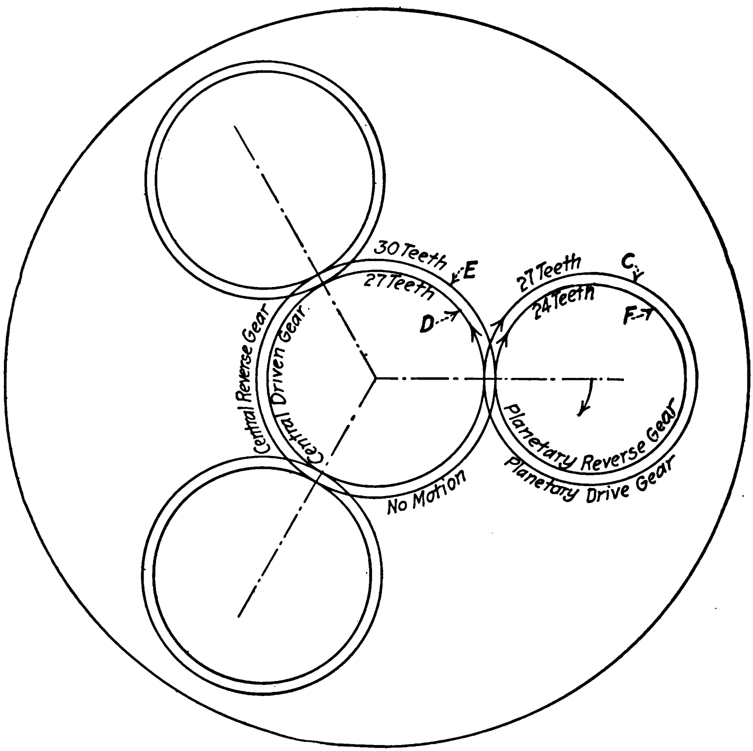

Fig. 7—Action Of Gears In Reverse

Adjustment.—Keep the transmission case properly filled with a good grade of oil at all times. See that clutch is correctly adjusted. Always have the same amount of tension on all three clutch fingers. When making repairs exercise care and do not drop any tools or pieces of metal into transmission case.

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Repairs.—Chief repairs will be replacing the following:—washers, bushings in brake drum sleeve, low speed drum bushings, triple gear bushings, reverse drum bushing, brake drum due to worn lugs, band linings and broken drums. Occasionally have to replace some of the gears.

Overhaul.—Disassemble and clean all the parts thoroughly.

Make sure that all magnet clamps and screws are tight.

See that magnets are parallel.

Examine the triple gear pins for looseness in flywheel. If loose replace with oversize pins.

Examine the triple gears for wear or loose rivets; if worn badly replace.

Examine the triple gears on pins, if there is over .005 play in bushings rebush them. When rebushed flanged face of new bushings should not project over .005 to .007 from side of triple gears.

Examine the triple gears for wear or loose rivets.

Note condition of driven gear sleeve bushing; if washers are badly worn or too thin, replace.

Fit transmission shaft to sleeve bushings with .002 play new job and .005 play on repair job.

Examine the rivets on slow speed drum. Look over gear teeth see that all are in good shape.

Try slow speed drum on the brake drum sleeve, allow .003 on new job and .005 on repair job.

Inspect rivets and gear teeth on reverse drum. Fit to slow speed drum gear, with .003 play on new job and .005 on repair job.

Inspect driven gear. Try keys in keyways.

Assemble driven gear to brake drum sleeve. Outer face of driven gear should be about .010 in. below end of driven gear sleeve.

After assembling, see that all drums revolve freely.

Assemble transmission shaft to flywheel.

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Place drum assembly gears up, on the bench. Assemble triple gears to drum gear assembly with punch marks on triple gears toward driven gear. Setting of gears may start at any point on driven gear. Assemble the sets of triple gears nine teeth or 120 deg. apart. After triple gear is assembled to drum assembly pick up complete gear units and place them on gear shaft and on the pins in the flywheel.

Place Woodruff keys that hold small disc drum on transmission shaft. Drive on disc drum securely, put in cotter key and spread so that set screw does not loosen up. See that drums are free and that there is not over 1-32 in. end play in brake drum. This is important.

Assemble discs, beginning with a large one, alternating with small ones and ending with large one, 25 in all. Place push ring in position.

Release tension on clutch fingers by compressing clutch spring and placing drive plate cap screw under clutch shift.

Place drive plate in position and secure same. Remove drive plate cap screw from under clutch shift. Wire from one drive plate screw to another.

When clutch is properly adjusted, there should be 13-16 in. space between lower side of clutch shift and drive plate.

When clutch spring is properly adjusted the spring will be 2 in. high.

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CHAPTER IV.

THE REAR AXLE.

Types of Rear Axles.—There are two general types of rear axles, the dead axle and the live axle.

Dead axles are stationary with the wheels running free on the end of the axle, the wheels usually revolved by chain and sprocket. There is no provision in the axle itself for driving the wheels.

Types of Live Axles.—Live axle is the name given to axles that revolve with the wheels. They are known as plain live axle, semi-floating, three-quarter floating and full floating axle.

Function of the Rear Axle.—The function of the rear axle proper is to transmit and transform the power received from the engine (through the transmission) and to distribute or deliver that power according to the resistance met with by the rear wheels.

Types of Live Axles.—A plain live axle is made in two sections, the differential gear being placed between its inner ends. This makes it necessary to support the axle parts in a strong housing and to brace it, in order that the parts of the axle do not sag or get out of line. The axle is contained in a housing which is a metal covering entirely surrounding it; the differential gear is in a smaller housing of its own, also inside of the axle housing. The housing extends to the wheels and inside of the housing we have ball or roller bearings. These bearings run between the axle and the inner side of the housing. There are also bearings at the inner end of the two parts of the axle, as it supports the weight of the car

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The Ford axle is a plain live axle.

Semi-Floating Type.—In the semi-floating type, more properly called the "fixed hub" type, the driving shafts turn freely within the housing. At their outer ends they are fixed in the hubs of the wheels and carry the bending stresses as well as the torque. The hubs of the wheels are fitted to the axle shafts by Woodruff keys and nuts. The hub caps are merely a protection for the ends of the hubs.

Three-Quarter Floating Type.—In the three-quarter or flanged shaft type the housing extends into the hubs of the wheels as in the full floating type, but the ends of the driving shaft are connected rigidly by flanges with the wheels so that the shafts take almost all the bending stresses and all the torque. In the flanged shaft axle, especially when only one bearing is used under the center of the wheel, the stresses are similar to those in the fixed hub type.

Full-Floating Type.—In the full-floating type of axle all the bending stresses, due to static force and skidding force are carried by the housing. The driving shafts turn freely within the housing and bear only the "torque" or stress of turning the wheels. The shafts are said to float within the housing. In the full-floating axle the shaft can be more easily removed for repairs; this is an advantage. The Society of Automotive Engineers' distinction between the three types of axles is as follows:

Semi-Floating.—Inner ends of axle shafts are carried by differential side gears (differential carried on separate bearings.) Outer ends of shafts are supported by bearings.

Three-Quarter Floating.—Inner ends of shaft carried same as in semi-floating. Outer ends of shafts supported by the wheels. Only one bearing is used in each wheel.

Full-Floating.—Same as three-quarters floating except that each wheel has two bearings. Wheels do not depend on the shaft for alignment.

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Advantage of Full-Floating Over Semi-Floating.—The advantages of a full-floating axle over a semi-floating axle are, that in the semi-floating type of axle the wheels are secured rigidly to the drive axle and are supported on bearings between the latter and the axle tube, the drive axles of the "floating" axles are flexibly clutched to the wheels, run on separate bearings and carry no weight. The semi-floating drive axle must not only transmit the driving torque, but must support the wheels besides, while the floating drive axles receive tortional strains only (the weight of the car being carried by the axle housing).

The bearings on which the wheels of a floating-axle are mounted are outside of the axle tubes and easily accessible, while those of the semi-floating are between the drive axles and the tube, hence are not as accessible.

The drive axles on a floating axle may be removed, permitting the differential to be taken out without disturbing the wheels or their mountings. This is impossible with a semi-floating axle, as in this type the housing must be entirely removed from the car together with the wheels, axle and differential.

The expense of manufacturing a semi-floating axle is much less than that of the floating type, and they have given every satisfaction where they have been properly designed.

The most important parts of the rear axle assembly are:

- The Universal joint
- The drive shaft
- The drive shaft housing
- The drive shaft roller bearing housing
- The drive shaft pinion
- The differential drive shaft
- The differential assembly
- The two axle shafts
- The two hub brake cam shafts
- The two hub brake pull rods
- The two hub brake shoes
- Right half rear axle housing
- Left half rear axle housing

In addition to the above parts there are several bearings which occur along the power line, the definition and purpose of which will be taken up later.

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The Universal Joint—Its Purpose.—The purpose of the universal joint is to change the level of the power from the crankshaft to the lower level of the wheel hubs.

Description of the Universal Joint.—Considering the transmission as an integral part of the motor, the universal joint is the first part of the rear axle assembly to receive the power from the motor, therefore, it is heat-treated and hardened to insure long life.

The universal joint consists of a male and a female knuckle joint which are assembled in two rings—riveted together. When assembled this forms a link in the train of power transmission through which power can be sent at any angle not exceeding 45 deg. The total angle in the Ford car is 25 deg. or, in other words, the angle of the drive shaft with the transmission shaft is 12 1-2 degs. The male knuckle has a square end which slips into a square hole in the transmission drive plate assembly. The ball joint acts as a housing for the universal joint and holds it rigid and at the proper distance from the transmission. The female knuckle of the transmission fits over and is pinned to the square end of the drive shaft.

Description of Drive Shaft.—The drive shaft or propeller shaft as it is often called is 53 5-8 to 53 3-4 in. long. On the upper end it is square and tapers at the other end for about 1 ft. It runs through the drive shaft housing or torque tube to the differential assembly in the rear axle housings. The drive shaft pinion gear is keyed to the tapered end and drawn up by a 5-8 in. x 18 thread castellated nut and cotter pinned.

It might be well to note here that there are three bearings on this drive shaft. First, the babbitt bearing at the forward end of the drive shaft, just in back of the universal joint. This babbitt bearing is placed there because there is very little wear or bearing strain at this point. In reality this bearing is simply a guide bearing. Next we have a Hyatt roller bearing at the

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rear end of the drive shaft just in front of the drive shaft pinion and immediately in front of the roller bearing to take care of the end play or end thrust caused by the bevel gears connecting the drive shaft and the differential. When the car is in motion there is a tendency for the drive shaft to thrust up toward the front. This is due to the fact that the drive shaft pinion is a bevel pinion and meshes with the differential drive gear which is also bevel. This end thrust pushes the bevel drive shaft pinion forward. Directly in front of this pinion is the drive shaft roller bearing and in front of this the ball bearing which butts against the flange of the drive shaft tubing. Thus it can be seen that this end thrust or end movement is stopped by the roller bearing and the ball bearing. Unlike most bearings this ball bearing is not to provide a bearing surface for the shaft to run on, but to eliminate friction in a plane at right angles to the axis of the shaft.

The Assembly of the Drive Shaft.—In assembling these parts on the drive shaft, the ball bearing is placed on first. It is prevented from going beyond its proper approximate position by the shoulder which is formed when the end of the drive shaft is finished. A thick washer is next put on the shaft so that the end motion of the roller bearing will not wear into the ball bearings. A hardened sleeve is pressed on to the drive shaft which is the bearing surface within the roller bearing. The drive shaft roller bearing runs within a hardened sleeve, called the drive shaft roller bearing sleeve. This sleeve is pressed into the drive shaft roller bearing housing, so it can be seen that this roller bearing runs between two hardened surfaces.

The Differential.—We now come to the differential, the next point in the power line and by far the most important part of the rear axle assembly. The bevel pinion on the drive shaft and the bevel ring gear on the differential case transform the motion from the axis of the drive shaft to the axis of the differ-

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ential, which is the second change in direction effected by the rear axle as an assembly.

Function of the Differential.—The differential is a mechanical device whereby the power delivered from the propeller or drive shaft is distributed to each of the axle shafts according to the resistance met with by them.

The Differential Assembly.—In order to get a clear conception of any contrivance we must first know of what it is composed. The parts of a differential are few, being only eight in number. These are (1) the right half of the differential case, (2) the left half of the differential case, (3) the differential spider, with three arms, (4) the three differential pinions and (5) the two differential gears.

Instead of having a solid rear axle, the axle shaft is in two halves. On the inside end of each of these is keyed a bevel gear, placed far enough back to allow a short end for a bearing. A short distance from this end a keyway is cut around the shaft. After being keyed onto the shaft the differential gear is pressed far enough back to allow two half rings, or circle keys, called differential lock rings, to be placed in the aforementioned slot around the axle shaft. Then the gear is forced forward and over the lock rings, holding them in place. This keeps the gear from coming off the axle shaft when the wheel is tightened on the other end of the shaft.

On the back of the differential gears is left a hub which is ground to a bearing finish for wear on the differential case. After placing the axles with the bevel gears keyed thereto in the proper place in the differential case, the three differential pinions are placed on the arms of the spider, and the spider is placed over the end of one shaft, which fills one half of the hole in the center of the spider and leaves the other half for the end of the other axle shaft. A fiber washer 1 in. x 1-32 in. in diameter is placed between the two axle shafts to deaden the noise by preventing the two shafts from butting together. The

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other half of the differential case is next placed over the gear on the end of the other shaft. The two differential gears are then placed in mesh with the pinions on the spider, and the two halves of the case are then drawn together by three studs 3-8 in. x 24 threads and 2 1-2 in. long. Thus, the differential proper is assembled with the two axle shafts keyed thereon. The large ring gear or drive gear has to be bolted to the left half of the differential case and it is ready to be put into the axle housings.

Bearings—Definition.—A bearing is that part of a mechanical arrangement which, besides carrying the load imposed upon it by the shaft associated with it, allows the shaft freedom to revolve.

Bearings—Why Necessary.—Before the advent of the bicycle and the motor driven vehicles there was no necessity for such anti-friction devices as ball and roller bearings. About the most commonly used bearing at that time was the babbitt lined cast iron or steel box in machinery, and the common wagon bearing lubricated by a good grade of axle grease. The machinery was not subjected to the heavy duty strain of the present day efficient factory. The wagon, if it had a heavy load, moved very slowly. A buggy or other lightly loaded conveyance, while going at a greater speed, needed only a little more attention given to the application of axle grease, but when the high speed modern automobile was developed it became an absolute necessity to contrive some method of reducing resistance, which of course meant a saving in fuel and at the same time must be of such quality that little attention need be given them to keep them in good running order—hence the ball and roller bearing of today.

On the rear axle shafts proper there are four roller bearings. The roller bearings are placed at the flange ends and also at the bell ends of the axle shaft housings. It is necessary to have a hardened sleeve on the axle shaft for these bearings to run upon for the load is divided between the several bearings.

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Roller Bearings—Description.—All roller bearings used in the Ford car are made of a high Chrome nickel steel of rectangular cross section and wound in spiral form, the rollers are held in place by the races in the "cage" which is composed of a flat ring at each end of the bearing. These rings are held together by bars. In the case of the drive shaft bearing there is a bar between every two rollers and it is known as the heavy duty type and the races are made of a high carbon steel on account of the high rate of speed as compared with the races on the axle shaft bearings which are made of low carbon steel carbonized and case hardened.

The rollers are assembled in the "cage" so that the spiral runs in the opposite direction on every other one. This condition assists greatly in the lubrication, as the oil will run to the left on one roller and to the right on the next one, keeping the rollers and races perfectly lubricated.

When assembling, the perfect alignment of the races in the housing is most important, as great damage can be done and the bearings may be ruined. In the case of two bearings of similar type, if one gives perfect satisfaction and the other does not, the trouble can often be traced to imperfect assembling as the races are made to fit the bearings and should give very little trouble. The flexible roller can adapt itself to slight irregularities that occur from excessive weight at different points of bearing.

The bearings used on the rear axle run inside of a split race or lining, the slot is of "V" shape to cause a continuous contact when in operation, there are projections on the lining used to locate it in the housing and the hole in the one on the outer end of the axle is used for lubricating purposes. When the cages are assembled the bars are welded in place and it would be a very difficult matter to relocate them without the proper tools. Should they get out of line, it is best to replace them rather than to attempt to repair them.

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Linings—How Fitted.—Linings should fit into the housings with a "press fit," that is to say one should be able to force the lining into place without the use of a hammer, by merely using a piece of wood and tapping lightly. Never use a hammer on either ball or roller bearings, if they will not assemble without driving something is wrong with the fitting.

Thrust Bearings.—On each side of the differential case is a thrust bearing. Each is composed of two steel washers with a babbitt washer between. One of these steel washers is dowelled to the bell of the axle shaft housing and the other is dowelled to the differential case. Obviously, the one fastened to the housing will remain stationary, and the one fastened to the differential case will revolve with the case. This will distribute the attendant friction over a larger surface.

Purpose of Thrust Bearing.—The purpose of this thrust bearing is to take up the end play and to minimize the friction which must necessarily occur when the car is rounding a corner, or when the one wheel is lower than the other,—a condition frequently met with on country roads.

Let us go back once more to the differential and its purpose. As stated before, the differential is a mechanical device whereby the power delivered from the propeller or drive shaft is distributed to each of the axle shafts, according to the resistance met with by them.

For example, when the car rounds a corner the outer wheel is traveling faster than the inner wheel; or, looking at it from another point of view, there is more resistance offered to the inner wheel, and it must necessarily travel slower. The wheels are keyed to the axle shafts, and so the revolutions of the axles are the same as the wheels.

Another case of unequal resistance to the two wheels is when one of the wheels is in the mud or on a slippery spot of pavement, when the other wheel is on hard ground or dry pavement. If the power be applied at this time the wheel in the mud or on

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the slippery surface will revolve, while the other will remain more or less stationary. The differential was devised mainly for the first cause, i. e. rounding corners, but unfortunately it works out disadvantageously when one of the wheels is in the mud.

It is the function of this differential mechanism to equalize and distribute the power to the two driving wheels as needed.

On some heavy trucks there is placed what is called a differential lock, to be used in such cases, but this has proved rather unsuccessful as it throws all of the strain on one side of the axle. The better plan is to gain traction for the wheel that is in the mud or sand by means of boards, or something wrapped around the outside of the wheel.

Explanation of Action in Differential.—Taking an assembled differential and clamping the case in a vise, if you apply power to one shaft, the opposite shaft will revolve in the reverse direction. This, it can readily be seen, is due to the fact that the three small pinions being rigid with the spider and case, revolve and cause the counter motion of the other shaft.

If you clamp one of the shafts in a vice and turn the other shaft, it will be noted that the differential case revolves in the same direction, but only one-half as fast. Upon looking in the differential case during this process you will see that for every two teeth on the gear that is being turned on the shaft, the pinion gear on the spider turns but one of the stationary gear, the other tooth space having gone into turning the differential case that distance forward. The same holds true in the reverse action, on applying power to the differential case, holding one shaft rigid and leaving the other free, the shaft makes twice as many revolutions as the case. It matters not what ratio the two bevel gears are to the bevel pinions, the action will always be 2 to 1.

Removing and Replacing.—Raise rear end of frame and remove rear wheels, remove four bolts connecting universal ball

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cap to transmission case and cover, disconnect brake rods, remove nuts holding spring perches to rear axle housing flanges and pull out assembly. In replacing, see that brake rods are adjusted properly so that an equal amount of friction is applied to both wheels when emergency brake is used, also all nuts drawn up tight and cotter-pinned. In replacing rear wheels, be sure that nuts on axle shafts are as tight as possible and cotter pins in place.

Axle Repairs.—There can be up to .005 in. play in the universal joint, when yoke fits into ring, but rings must be tightened together and well riveted.

Drive shaft bushing can have .003 in. play between shaft and bushing, also .005 in. end play between face of bushing and universal joint face. Drive shaft pinion and ring gear should run from .001 in. to .010 in.; tighter than .001 in. makes a grinding noise, and even .010 in. a rattle or roaring noise. Both gears should be inspected for cracks or hardness. Care should be taken when putting pinion gear on drive shaft to see that key is in proper place and clears on top so that gear will be drawn tightly on *taper only* with nut drawn tightly and cotter pin in place. Axle and drive shaft roller bearings can have .005 clearance and should not have to be forced into place, allowing a 1-16 in. to 1-8 in. end motion for lubricating and wearing purpose.

Differential.—Have all moving parts free but not loose. Hub bearing on gear to hole in case should be from .002 in. to .004 in. free to allow for oil. Spider pinion and axle gear .001 in. to .010 in. play. Spider should be solid in hole when case is down tight. Take hold of both ends of shaft after differential has been assembled. The case can have 3-8 in. rock or motion. Inspect case closely for cracks. Make sure that screws holding ring gear to case are properly tightened and wired, at least two together, and also that stud nuts are properly wired, three together. End play of 1-32 between ends of axle shafts is

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O. K. Care should be taken in drawing wheels on to the axle shafts. See that key is not riding on keyway in shaft, also that keyway is not too large for key sideways. Wheel should be drawn up tight on taper only, and nut cotter-pinned. Be careful not to put the screw that holds drive shaft roller bearing sleeve in place on drive shaft so that end strikes roller bearing. When pressing inner roller bearing sleeve on to drive shaft, be careful not to get it too tight or too loose. If too tight it splits; if too loose it will turn on shaft. Watch pinion key—see that end does not come out far enough to catch roller bearing retainer and stop motion of bearing. As a rule cracks in bell of axle housings can be repaired by spot welding. If flange is cracked any place between spring perch hole and lower radius rod fork-hole it will be necessary to scrap housing. Cracks on other side of flange or on hub can be spot welded. Be sure that all nuts and bolts are tight and well wired or cotter-pinned. Make sure that steel thrust bearings next to differential case and on inside ends of housings are on pins so that they will not turn—this is very important.

Truck Axle Removing, Replacing and Repairs.—The instructions for removing and replacing the touring car axle assembly are applicable to the truck axle. To disconnect the universal joint from the drive shaft, remove the two plugs from the top and bottom of ball casting and turn shaft until pin comes opposite hole, drive out pin and the joint can be pulled or forced away from the shaft and out of the housing.

To disassemble the rear axle and differential, remove the bolt in front end of radius rods and the cap screws holding the drive shaft tube to the rear axle housing. Next, remove the rear axle housing cap; also the bolts which hold the two halves of the differential housing together, remove cotter pins, bolts and nuts from the differential housing and pull apart. In reassembling use new paper liners.

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To Remove the Worm.—Drive out the pins which hold the coupling to the worm and drive shaft. Then remove the felt washer, roller bearing sleeve and roller bearing by slipping them over the coupling. Drive the coupling off the drive shaft, then force the worm from the coupling. Removing the worm nut will permit the removal of the retaining washer, thrust bearing and rear worm roller bearing. In reassembling, be sure that the pin which holds the retaining washer stationary is in place.

Repairs.—The worm is assembled with .006 in. to 0.15 in. end play. The bearings of the worm must not exceed 1.623 in. or be less than 1.615 in. Drive shaft to worm coupling should be drive fit. After parts are assembled, worm should be turned free by hand a few revolutions to determine whether or not parts are true and without high spots.

Dimensions—Drive Shaft Assembly:

Diameter and length of drive shaft 53 5-8 to 53 3-4 x 1 3-32 in.

Drive shaft sleeve-inside diameter 1 in. x 3 1-16 in. long.

Drive shaft roller bearing—length 2 5-8 in.

Thread on end of drive shaft—5-8 in. x 18.

Drive shaft tubing—50 1-2 in. long.

Drive shaft tube is 49 5-16 in. from face to center of universal joint ball.

Drive shaft bushing—1 in. bore x 1 3-4 in. long.

Differential Assembly:

Hub diameter of differential gear 1.808 in.—1.809 in.

Gear case diameter—5.248 in.—5.249 in.

Diameter of gear end of axle shaft—1.062 in.—1.063 in.

Bearing end of axle shaft 1.062 in. to 1.063 in.

Length of axle shaft 31 1-32 in.—31 3-32 in.

Bronze or babbitt thrust plates and steel thrust plates are all 3 3-4 in. outside diameter. Bronze or babbitt .198 in.—.202 in.

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Steel thickness .0875 in.—.0885 in. prior to July 1916.
New .085 in. to .087 in.
Diameter of center hole in thrust plates 2.250 in.
Fibre washer 1 in. x 1-32 in.
Height of assembled differential case 3.623 in.—3.625 in.

Housings.—Axle housings—26 3-4 in. Housing diameter for roller bearing sleeves—2.208 in. to 2.211 in. Diameter of bell—8.752 in.—8.754 in. inside and 9 1-4 in. outside.

From center of ring gear in housing to the face of housing for drive shaft tubing is 4.592 in.—4.595 in. If this measurement is not accurate assembly cannot be made with proper meshing of drive shaft pinion and ring gear.

Brake pull rod clips should be 18 in. from center of clips to center of radius rod bolt holes.

Questions and Answers on the Rear Axle.

Q. What is the difference between right and left housings?

A. The right housing usually carries the housing oil plug, left has none. This, however, is not an infallible point of difference. The right housing has a flange on the edge of the "bell". The left housing is recessed on the edge of the "bell" to fit the right one. The spring perch hole is the quickest way to recognize the right and left housings. If spring perch holes are at the top of each housing, the housings are in proper position right and left.

Q. How can you tell right hand rear axle roller bearing sleeve from left?

A. Hold the roller bearing sleeve in the hand so that retaining lug on surface of sleeve touches the first finger with palm of hand up. If the oil hole in sleeve is at the left, the sleeve is a right hand sleeve. If the oil hole is at the right, the sleeve is a left hand sleeve.

Q. Explain the difference between right and left brake cams.

A. Hold the cam end in the hand, with cam vertical. The pin hole in the shaft points towards the left on right hand cam and towards the right on left hand cam.

Q. What is a differential gear? What is its purpose?

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A. The differential gear is the gear used on the rear axle for taking care of the varying speeds at which the rear wheels must run in turning a corner or in any way changing the direction of the car from a straight line. The wheels traveling farthest must travel fastest, so the rear axle is divided into two portions and a set of gears interposed which allow this action to take place, and yet drive the wheels the same rate when the car is traveling on a straight line. The differential permits each wheel to travel independently. The differential is made necessary because the rear wheels are keyed to the axle shaft. In a wagon the necessary variation in speed of the wheels is permitted without gearing because each wheel can revolve on the axle.

Q. What is the ratio of differential gear to spider gears?

A. The spider and differential gear ratio is two to one. The spider gears, however, do nothing but transmit the motion from one axle gear to the other. Their size or number of teeth does not affect the rotation ratio.

Q. What is the use of the spider gears?

A. The spider gears act as a pivot for the differential gears to revolve upon when turning and to connect them as a unit when traveling in a straight line. They are like the swivel of a whiffle tree permitting motion or straight pull. They do not affect the turning ratio of the differential gears.

Q. Explain the action of the differential.

A. If the resistance to traction is the same on both rear wheels the entire differential assembly revolves as a unit. The spider gears remain stationary on their studs and act simply as a lock, forming a driving connection between the two axle gears. If the resistance against the driving wheels varies so that one wheel tends to revolve faster than the other, the spider gears will not only turn around on their own axis, but at the same time will run around the gears on the axle shafts, because the bevelled gear moves forward and carries with it the stud on which the spider gear revolve. The spider gears can then turn independently of one gear running over it without turning it and yet act as a clutch on the other gear and axle, to force them in the same direction as the right gear and at a ratio of speed which will depend upon the difference in resistance between the rear wheels and ground.

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Q. If one axle shaft or wheel is held stationary with rear axle jacked up, while motor revolves the differential gears, how does this affect the action of the other shaft or wheel?

A. The other shaft will make twice the number of revolutions secured when both wheels revolve. This is because of the action of the differential gears in addition to the regular ratio of motor and rear axle revolutions. The spider gears not only turn on their own axis, and by acting as a clutch against the stationary gear, force the free axle gear around one revolution, but the spider gears also run around the gears on the axle because the bevel gear moves forward and carries the spider gear studs with it. If spider gears were solid on their stud, the bevel gear would carry them around every revolution and make the free axle turn once. In addition, the turning of the spider gears on their own axis, makes another revolution of the free axle because both axle gears are the same size.

Q. If engine is stopped and one rear wheel turned by hand to the right, while car is jacked up, what is the effect on the other wheel?

A. If one rear wheel is turned to the right, the other will turn to the left at the same speed, when axle is raised from the ground.

Q. What is the cause if one rear wheel cannot be held stationary with axle jacked up and engine running?

A. If rear wheel cannot be held stationary with engine running and axle jacked up the differential gears are too tight—are locked from one of the causes named later.

Q. What would be the cause of the rear wheels NOT turning while motor is running and clutch in?

A. The key of drive shaft pinion gear is out or sheared off, permitting the drive shaft to revolve without turning the pinion gear and so not revolving ring gears or differential gear. Ring gear bolts may be all broken off, permitting ring gear to revolve by itself. A broken axle shaft close to the differential gear would have the same result.

Q. Give number of teeth on various gears in differential assembly.

A. Drive shaft pinion 11-tooth; Bevel ring gear 40-tooth; Spider gears 12-tooth; differential gears 24-tooth.

Q. Name the main parts of the drive shaft assembly.

A. The complete drive shaft assembly includes:

Drive shaft roller bearing casing with sleeve and plug for

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holding sleeve,
Thrust bearing collars,
Ball bearing assembly,
Drive shaft $1\frac{3}{32}$ in. x 53⅝ in.,
Drive shaft sleeve, 1.022 in. bore, $3\frac{1}{16}$ in. long,
Roller bearing 2⅝ in. long,
Drive shaft pinion key, pinion and castle lock nut ⅝ in. x 18,
Drive shaft tubing .50½ in. long,
Universal joint assembly and pin.

Q. How would you dismount a drive shaft assembly after it is removed from axle assembly?

A. To disassemble the drive shaft from its tubing:
Remove plugs from ball castings,
Drive out universal joint pin,
Remove universal joint assembly,
Pull out drive shaft from tubing,
Remove castle nut and drive off pinion,
Take off drive shaft bearing casings.

Q. What is the purpose of the thrust ball bearing in drive shaft assembly?

A. To compensate for the end movement of the drive shaft, a special ball bearing assembly is used. The end motion is caused by the driving reaction on the angular teeth of the ring gear producing an end thrust against the pinion shaft. The roller bearings care for the side motion and the special ball thrust bearing cares for the end thrust.

Q. If too much play exists between the pinion gear and ring gear how may it be adjusted?

A. Excessive play between pinion and bevel gears when caused by end play of drive shaft and tubing may be adjusted by inserting a new front bushing in the drive shaft housing. This bushing is of babbitt, 1 in. bore and 1¾ in. long. This play is sometimes caused by wearing of differential thrust plate against the left face of casting. Be sure to measure up thickness of new thrust plate before installing. It should be .0875—.0885 in. on assemblies prior to July 1916 and .085 in. to .087 in. subsequent to that date

Q. What is the reason for using a universal joint coupling?

A. The universal joint coupling permits rotating the drive shaft

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even though it is an angle with the engine crankshaft. This slope is necessary because the differential and driving gearing in the rear axle are carried lower than the engine so some driving coupling must be provided which is capable of compensating for this lack of alignment. The ball housing surrounding the joint permits the twisting and turning of the axle as the wheel travels over uneven surfaces.

Q. On which side must ring gear be placed in building rear assembly?

A. The ring gear must be placed in the left housing of the rear axle assembly to make the wheels turn in a forward direction. The wheels will run backward if assembly is built up with the ring gear in the right housing.

Q. What is the cause of a noisy rear axle?

A. Rear axle will be noisy:
If pinion and ring gears mesh too closely,
If ring gear becomes warped for any reason,
If there is a high spot on pinion or ring gear of differential gears,
If thrust washer comes off, the pins holding it in place,
If the ring gear is out of round.

Q. What are some of the causes of a tight or locked differential?

A. Differential will be tight if:
The pinion gear is too tightly meshed against ring gear,
The spider shafts hold left and right sections of case from close contact,
The hub of differential gear binds on its bearing in differential case.

Q. Of what use are the rear axle radius rods?

A. The rear axle radius rods hold the axle housing at right angles to the drive shaft tube.

Q. Where should the brake pull rod clips be fastened on the radius rods or rear assembly?

A. Brake pull rod clips should be 18 in. from rear ends of radius rods.

Q. What is meant by "full floating axle"? What type axle has Ford car?

A. The "full floating" type of rear axle is one that is used only to drive the rear wheels and carries no weight of the car whatsoever. The two halves of such an axle can be withdrawn from either rear wheel without even jacking up the car from

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the floor. The Ford car has a "plain live" rear axle—each half of which carries a portion of the car weight while the housing carries the balance.

Q. What size and thread has end of rear axle shaft?

A. Lock nut on end of rear axle shaft is ⅝ x 18.

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CHAPTER V.

THE FRONT AXLE.

Front Axle Construction.—The front axle of a motor car is doubly important. It not only supports the weight of the front end of the vehicle, but must be strong enough to withstand terrific blows; as when the wheels strike some obstruction while the car is traveling at high speed. Furthermore the car must be guided through this axle.

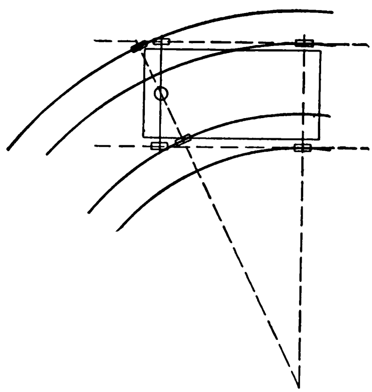

Fig. 8.

Early Forms of Axles.—The earliest form of axle was copied directly from the horse drawn vehicle, that is, the wheel spindles and axle body were one straight unit, and this unit was pivoted at its center. (See Fig. 8.) The steering was simple and positive, just a vertical shaft and horizontal lever being employed. Since the machines then were unable to attain a speed over four miles per hour this construction was quite practical. However, it was

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not long afterwards that improvements in front axle and steering gear construction became absolutely necessary, and various devices were tried with, of course, various degrees of success. The objection to the original type of axle was that it was very hard to control. If a wheel were to strike a slight object or depression in the road surface, the lever, or "tiller" as it was called would be whipped from the driver's hands, and if there were no checking device the car might be immediately overturned. At all times the vibrations were transmitted directly to the driver's arms, so steering at that time was not only a dangerous and difficult job, but also very fatiguing.

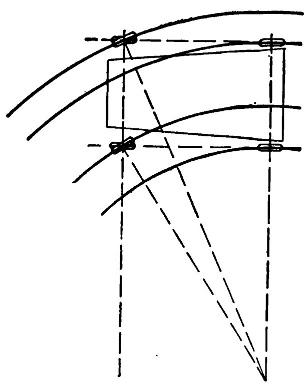

Fig. 9.

The Ackerman Type Axle.—Ackerman, an engineer, devised the axle which bears his name and which is at present universally employed. The axle body is attached firmly to the chassis of the car, through the front springs, but the wheel axles or "spindles" are pivoted to the main axle body. Thus the wheels may be set to any angle without disturbing the setting of the main axle. This construction affords much greater stability, and as the wheel resistance acts through much shorter lever arms, the energy necessary to control the axle is very greatly diminished. (See Fig. 9.)

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One spindle, either the right or left one, is controlled by the steering device. The other moves accordingly, being joined to the first by a tie rod which usually is adjustable. This tie rod may be placed either in front of the main axle or behind it as desired by the designer. (See Fig. 10.) Placing it behind the

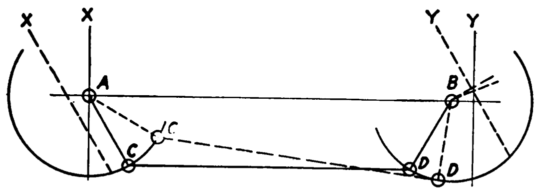

Fig. 10.

axle protects it, and furthermore it may be made shorter. In the construction of the front axle, a clever idea is brought out. If the wheel axles are parallel with the ground as in the main axle, the wheels themselves of course would be perfectly vertical, (See Fig. 11), and the resistance which must be overcome by the

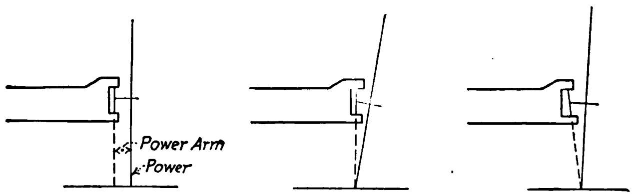

Fig. 11. Fig. 12. Fig. 13.

steering device and the driver, would be the road friction of the wheel multiplied by the distance to the pivot or spindle bolt, but if the wheel is set so that the point of contact with the road were in the line of the spindle bolt, (See Figs. 12 & 13), this lever arm is decreased and so accordingly is the effort. In order that

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the steering effort is reduced to a minimum in the perfect axle the center of the wheel hub or lines of wheel contact with the road and the pivot are coincident. This has been accomplished by some designers to a very great extent, but the complicated construction and cost does not offset the result obtained so the general method is to either incline the wheel or the spindle bolt.

There is three inches difference in the top and bottom measurements between the wheels of the Ford. Because of the inclination of the wheel they have a tendency to roll outward and pull away from each other. To counteract this tendency the wheels are "toed" in slightly from the true parallel position; about 1-8 in. to 1-4 in. is the Ford setting.

Since the wheels, therefore, flare outward at the top their ability to withstand a side blow, which is nearly always applied at the lower part as in resisting a turn, is reduced.

Axle Tilt or Castor.—Practically everybody today is familiar with the setting of the front wheel of a bicycle. The fork declines forward and because of this particular construction the rider so easily speeds along "hands off". This inclined pivot idea is also utilized in front axle construction. By tilting the axle backwards the desired result is obtained and also the axle is in a more favorable position to resist jolts and shocks, but of the two, the main object of tilting the axle is stability. Any shifting of the wheels from the straight ahead position works directly against the weight of the car so the tendency is for the wheels to swing back to their original position. The Ford axle is tilted by the spring perches 5 1-2 deg.

Construction of Ford Axle.—As for the construction of the axle itself; the lightest construction possible, of course, is desired to reduce the final weight of the car, but weight is not as big a factor as strength. Not only is rigidity and hardness required but toughness as well. An extremely hard axle will crystallize more readily and break more easily than one which is

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less hard but tough instead. "Better a bent axle than a broken one."

Some designers use steel tubing. This gives a strong light axle which will absorb shocks readily but when it is once bent it is impossible to restore it to its original shape and strength. Of any design, the Ford "I Beam" construction is considered the most practicable. It is forged from a solid bar and not only is light but strong as well. (See Fig. 14.)

The steel used is Ford vanadium steel. This type steel is also used in the spindles and spring perches, and is one of the very best steels produced.

Under test the Ford axle has been twisted, cold, seven times around and then retwisted without seriously impairing it. If the axle is bent it must be straightened cold, for if heated to a red heat there is great danger of distempering the steel.

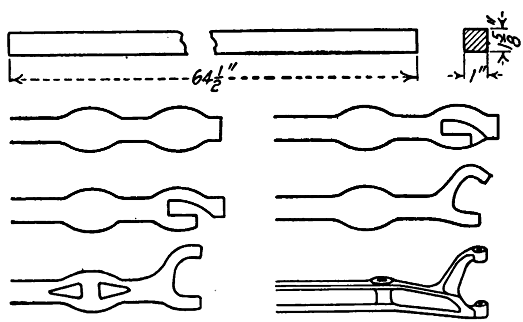

Fig. 14.

The Wheel Axles or Spindle Assemblies.—The wheel axles or spindle assemblies are set between bosses integral with the main axle body. A hardened steel bolt holds each in place. These bolts are drilled at their heads and provided with small dust caps, thus each is a combined oil cup and bolt.

The spindle assembly consists of the wheel axle, steering arm, inner or stationary cone, also called the ring cone, the outer

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cone, the steel washer and hex castle nut. The steering arm and ring cones are tight fits and must be pressed into place, the arm held by a hex castle nut and cotter pinned. In order that the bolt may slip easily through the tie bar yoke and steering arm, the hole on the arm for this purpose is lined up carefully after the arm is secured. The right spindle is threaded left hand and the left hand spindle the opposite way. The friction, therefore, of the wheel hubs tends to loosen the outer adjustable cones, preventing the binding of the balls in their races resulting in their being chipped or broken. Great care is taken in cutting the ball races of the cones so that a smooth, true surface will be presented to the balls. A special tool of "stellite" steel is used for this purpose, and races are carefully gauged for trueness, only .003 in. being allowed.

Radius Rods.—As before mentioned the front axle of an automobile is fastened to the frame by means of the springs. Therefore, the drive must be constructed accordingly. Ford uses only one spring, it being placed parallel to the axle, so instead has only one point of fastening to the frame. Therefore, some means of preventing the spring and axle from twisting, using this place of fastening as a pivot, is necessary. Also because of its peculiar position it is plain that the drive must be received through some other medium than the front spring; hence the radius rods.

Care must be taken to see that these rods are always in good shape, that they are not bent or loose. A bent rod not only would be deficient because of weakened condition but also because the axle would be drawn back slightly from the parallel position.

These rods, or tubes, are pressed cold from sheet steel and the seam brazed. So if once bent the original strength cannot be restored by straightening.

The point of fastening of the radius rods to car is a ball and socket joint brazed to the lower crank case.

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Tie Rod and Caps.—From a ball on the tie rod, a rod is led to the ball arm of the steering gear. This connecting rod is called the drag link, and it is through this rod that the spindle assemblies are controlled by the steering gear. Formerly one of the sockets at the ends of the rod was forged from the rod itself while the other was made separately and brazed. Now both are forged directly from the rod. These sockets must at all times fit snugly to the bolts to prevent rattling and resultant wear.

If after service the caps cannot be drawn down tightly enough, a small amount of stock may be filed from the flat face of the caps. This will allow their being drawn down to the required fit.

Construction of Springs.—The spring is made of six bands or "leaves" of vanadium steel. The springs are bolted together through their centers and the clips set in position. The clips hold the bands together and in alignment so that in a rebound the whole spring assembly will act as a unit and not throw the strain entirely on the first or eye leaf. It is very important that these clips be in position and tight at all times.

Spring Tests for Load and Endurance.—The Ford spring will stand a load of 2,000 pounds before it is straightened out, and around 35,000 continuous vibrations before it will break. At 2,000 pounds each leaf is practically a straight line and therefore rests firmly on its neighbor supporting it along the whole length at the same weight.

The test for endurance is performed on a special machine for that purpose. The spring is held by its ends and the center forced down and back again at the rate of 120 times per minute. Some springs have stood as high as 60,000 vibrations, but the average is 35,000.

The point of breaking varies from the center to practically any point of the length. Although being pierced in the center by the

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drilled holes, only about a third of the test springs break at this point.

Care of the Springs.—Springs should be lubricated frequently with oil and graphite. To do this disassemble the leaves and rub bearing surfaces smooth with emery cloth; pack them with graphite and reassemble. To prevent rust from accumulating paint the springs with a quick drying black paint. By doing these things you will greatly improve the riding qualities of the car and also insure longer life of the parts.

Repairs.—If the axle is bent and the proper jigs for straightening are available, it is all right to straighten it in service work. Never heat the axle to a red heat to straighten for fear of distempering.

Rebush or replace the spindles. If rebushed ream them to size. Replace wheel bearings in the cones. Repair ball joints at end of tie rod and drag link. See that all bolts and nuts are tight and cotter pinned and all moving joints well lubricated.

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CHAPTER VI

THE STEERING GEAR AND BRAKES

Steering Gear.—Practically all modern motor vehicles are steered by the front wheels, this method resulting naturally from the behavior of a vehicle thus controlled.

The steering gear includes the hand wheel which is turned by the driver, and all of the parts that carry the turning effort from this wheel to the front road wheels. The rear wheel controlled car had these chief drawbacks:—When making a turn the rear, of course, must describe an arc away from the point or object to be cleared. Therefore, if two machines were running

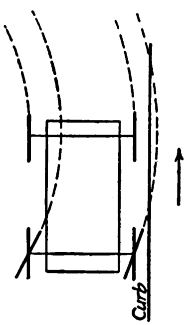

Fig. 15.

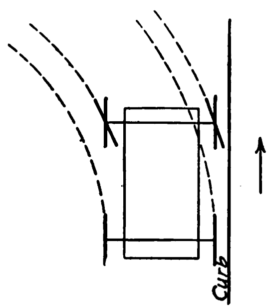

Fig. 16.

parallel it would be impossible for them to suddenly break away from each other, as, in one of them turning a corner, or a ditch, the wheels would first have to run directly towards the curb or ditch, which, in many instances may be impossible. Then there is the danger of "sideswiping." (See Fig. 15.) So handling a car of this type is not only difficult proposition but also a danger-

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ous one as well; the difficulties increasing with the length of the wheel base.

The original steering combination was copied from the horse-drawn vehicle as was also the car itself. The wheels were hung upon a straight solid axle which was free to be swung about a central pivot. A shaft and lever similar to the tiller of a row-boat controlled the angular movement of the axle. Thus the axle was like a long lever having its fulcrum in the center, and since the tiller, or working arm, for practical reasons had to be short, the load delivered was much greater than the force applied at the wheels. The energy then necessary to steady the axle under any speed whatever was far too great; road vibration

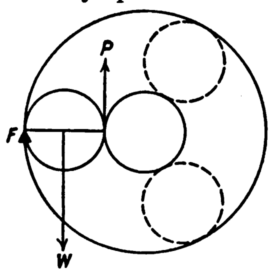

Fig. 17.

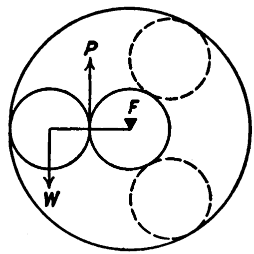

Fig. 18.

was of course, transmitted directly to the driver's arm, so the operating of the car was a tax on the strength and endurance of the driver.

This led to the irreversible type of steering gear; a gearing which would allow positive movement from the steering wheel but not in the reverse direction. The screw and nut type was one of the most satisfactory devices employed but the trouble was that it was too irreversible. The wheels were practically locked in the position they were set, so would not follow a road track. Then followed the semi-reversible, the worm and sector, worm and gear, gear and ratchet, etc., of which types the former has about supplanted the others. All types are used in which the prin-

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ciple of the simple lever are embodied, the work done on the one side of the fulcrum is always equal to the work on the other side. (See Figs. 17 and 18.) So although but a little force may be necessary to operate the steering mechanism, the force applied must act through a long distance and this is brought about by revolving the wheel. The greater the number of turns, the less the required force. However, these points must be taken into consideration. The greater the number of turns, that is, the movement ratio, the higher is the irreversibility factor, and the slower the action. So in designing a steering gear the ratio must be selected at a happy medium for the particular car intended. A light car may satisfactorily use a ratio which would prove useless for a heavy truck.

The Ford Steering Gear.—The parts of the steering gear which are fastened directly to the front axle are the spindle assemblies which are set between bosses integral with the main axle body. A hardened steel bolt holds each in place. These bolts are drilled at their heads and provided with small dust caps, thus each is a combined oil cup and bolt.

Spindle Assembly.—The spindle assembly consists of the wheel axle steering arm, the inner or stationary cone, also called the ring cone, the outer cone, the steel washer and hex castle nut.

The steering arms of this assembly extend towards the rear of the car and these arms are fastened together by a transverse rod called a tie rod. This tie rod is moved crosswise by a steering link, sometimes called a drag link whose one end attaches to the right hand end of the tie rod and whose other end is attached to the ball arm at the lower end of the steering column. Movement of this ball arm pulls the steering link one way or the other and through the tie rod and spindles the front wheels are turned. The tie rod is of such length that when one of the front wheels is turned the other turns also, but to either a greater or less degree than the first one. Regardless of the amount that either

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wheel is turned, it will be found that lines through their spindle point to one and the same point and that this point lies in a line drawn through the rear axle. (See Fig. 19).

The construction of that part of the steering gear which is directly acted upon by the hand wheel consists of a shell on the

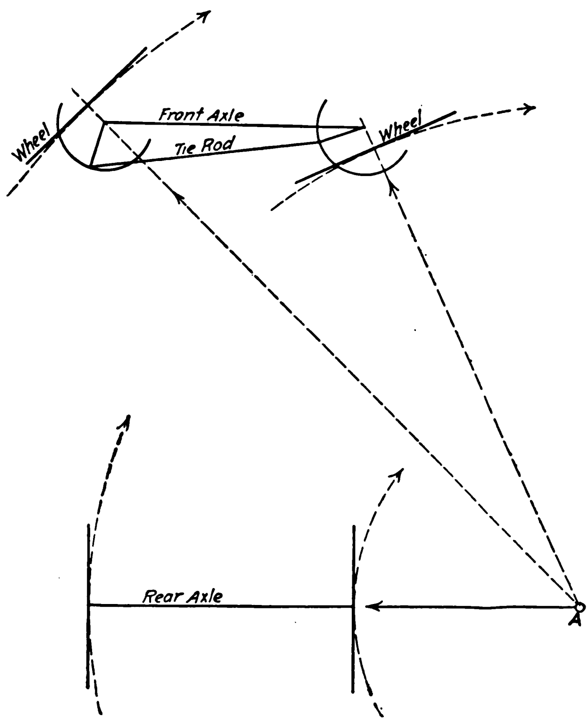

Fig. 19.

inside surface of which are gear teeth (36 in number). This shell is fastened to the upper end of the steering gear column housing and remains stationary. In mesh with the teeth in this shell are three small pinions, (12 teeth cut on each) which are mounted on a triangular plate fastened to the upper end of a

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shaft extending down through the center of the steering column. The steering wheel carries another small pinion which meshes with all three of the pinions which are attached to the steering column shaft

When the steering wheel is turned by hand it revolves the central pinion and in doing so causes the three steering shaft pinions to roll around the inside of the toothed shell. In traveling around the inside of this shell the three pinions carry with them the triangular piece on which they are mounted and the steering shaft is thus caused to go through part of a revolution.

It will be realized that it would require several revolutions of

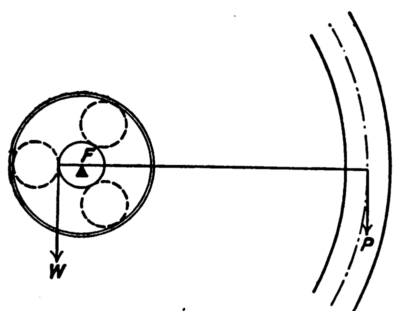

Fig. 20.

the steering wheel and its gear to cause the three pinions to travel all the way around inside of the shell. It therefore requires a considerable part of a revolution or even more than one complete revolution of the steering wheel to affect any change in position of the steering shaft. This reduction of motion increases the power applied by the driver to the road wheels and gives good control of the direction in which the car shall travel. (See Figs. 20 and 21).

Materials Used in Ford Steering Gear.—Because of the severe strain to which the steering apparatus of a motor car is subjected and the duties which it must perform, the lives of

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the car occupants depending upon the device, the steel used must necessarily be of the best quality. Toughness is more desired than hardness for the whole mechanism is forced to undergo, generally, sudden and severe shocks and any brittleness of the parts would result in sudden breakage. The only heat-treated parts of the steering assembly being the ball arm, the gear studs and the bushing for the driving gear shaft. The bracket which

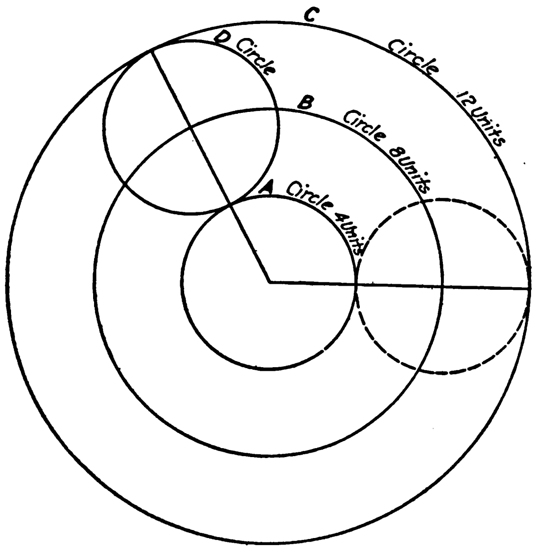

Fig. 21.

holds the column firmly to the frame of the car is of malleable iron. This metal absorbs shocks and vibration readily and being ductile resists breaking to a very great extent. The gears and main driven shaft are cold rolled steel. The gear case or internal gear of type W bronze, bronze used not only for the formerly mentioned reasons, but because it is easily and accurately machined.

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The Brakes.—Two separate and distinct brakes are provided on the Ford car. One of these brakes acts on a drum carried with the transmission gearing and is called the service brake, it is of the external contracting type and is operated by the right hand foot pedal. The other brake acts directly on the rear wheel hubs through drums fastened to the hubs and into which brake shoes are expanded when a pull is exerted on rods which attach to the controller shaft. This wheel brake is called the emergency brake and is of the internal expanding type.

The principal parts of the emergency brake consist of the steel drums which are solidly fastened to the rear wheels, and two shoes which expand inside of each of these drums. The service brake is carried in the transmission and consists of a band which encircles the brake drum and a foot pedal which acts to contract the band through linkage drawn tight when the pedal is pressed.

The service brake retards the motion of the car through its effect on the brake drum and sleeve, then on the universal joint and the drive shaft, then through the rear axle driving gears and differential to the axle shaft and to the wheels. The differential serves to divide the braking effect equally between the rear wheels and in this way serves the purpose of what would be called a brake equalizer were such a device built as a separate part of the braking system. The division between the rear wheels of the braking effect exerted by pulling on the hand lever is not determined by an equalizing device, but depends for equal action on maintenance of correct length of the pull rods. The length of these pull rods may be altered by screwing the forked rod ends one way or the other on the ends of the pull rods.

It is possible to apply a powerful braking action at the rear wheels by exerting a very light pressure on the reverse pedal. It should, however, be kept in mind that braking done by means of the reverse imposes a very severe strain on the transmission

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gears. It is always possible with any car to allow the engine itself to act as a brake in descending a hill of some length. This is done by turning the ignition switch to the off position, closing the throttle and then engaging either high or low gear. The engagement of high gear will cause the car to drive the engine at a moderate rate of speed and this will give sufficient drag to reduce the speed at which the car is traveling. Engagement of low gear causes the car to drive the engine very fast and will therefore reduce the speed of the car very quickly.

Gas and Spark Levers.—Under the steering wheel are two small levers—the right hand or throttle lever controls the amount of gasoline and air mixture which goes into the cylinders, the left hand lever controls the spark which ignites the gas in the cylinder of the engine.

The different speeds required to meet road conditions are obtained by opening or closing the throttle. Practically all the running speeds needed for ordinary travel are obtained on high gear and it is seldom necessary to use low gear except to give the car momentum in starting. The speed of the car may be temporarily slackened while driving through traffic or turning corners by slipping the clutch, that is, pressing the clutch pedal forward toward neutral.

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CHAPTER VII.

GENERAL LUBRICATION

Metal surfaces, although they appear smooth to the eye and touch are made up of minute irregularities which are visible when magnified. When two metal surfaces are brought into contact, these minute irregularities interlock, retard the motion and tear off the projecting particles. This tearing off of the projecting particles is the cause of wear of bearing surfaces. The duty of a lubricant is to keep the surfaces separate, being pressed out into a thin film on which the moving parts rub, thus preventing direct contact.

At present there are almost as many different lubricating systems as there are makes of engines. The trend in the last few years has been toward simplifying these systems, making them fool-proof as far as possible, and at the same time having their action positive. We will not go into detail concerning each individual type, but confine our discussion, rather to the Ford type. General design and operating requirements influence the oiling system requirements; and therefore, we cannot say that one particular type fills all needs. In most engines, however, some form of the constant level splash system will meet the requirements. Some designers place a circulating pump on the base of the engine to distribute oil later by gravity. Others force the oil through pipes to the various bearing surfaces. Still others adopted some means of maintaining a constant oil level in the crankcase, where the connecting rods splash the oil throughout the engine below the pistons, lubricating all moving parts by the oil or oil vapor thus distributed.

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The constant level splash system is the simplest of all satisfactory systems in use today. Even this system is divided into several classes, most of which employ some kind of pump. Every oiling system may be said to be a splash system to some extent, as the oil must in each circulate over the interior of the engine. It would appear then that the more simple the system (consistent with performance) the greater its advantages.

The Ford Model T System.—The oiling system employed on the Ford Model T car is known as the "constant level" circulating splash system. The oil is poured into the breather pipe at the right side of the front of the engine, from which it flows over the connecting rod troughs of the crank case lower cover (leaving them full) and into the lowest part of the crankcase under the flywheel. When the engine is running the oil in the bottom of the crankcase is carried by the flywheel and magnets near the top of the transmission cover. Here a portion of it drips into the funnel shaped upper end of the oil pipe where it flows by gravity down to the timing gears, returning once more to its original position under the flywheel. The oil pipe mentioned is the only one used. No pump is required in the Ford system. All moving parts of the engine are kept well oiled by this system. The only opening into the crankcase is the breather pipe. Any oil which may be "pumped" to the top of the push-rods is automatically drained back into the crankcase by two small holes, one just inside each valve door. The Ford oiling system is highly efficient, has proved satisfactory over a long period of years, and is more fool proof than any other in use today. The only attention required, other than replenishing the oil supply from time to time, is to wash out the crankcase every 1,000 miles. The oil level should be kept between the two pet cocks at the rear of the crankcase.

Laboratory Tests of Oils.—The following are a few tests by which the various oils are judged as to their suitability for certain conditions.

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Gravity Test.—The Baume Hydrometer is in general use throughout the United States. This instrument, carrying an arbitrary scale, when allowed to float freely in an oil or other liquid, sinks to a depth corresponding to the density of the liquid (this is the instrument commonly used in testing the electrolyte in a storage battery). The Baumé "Gravity" value is then the point where a surface of the liquid intersects the scale. The liquid is maintained at a constant temperature of 60 deg. F.

Specific Gravity is the ratio of the weight of a solid or liquid substance to that of an equal volume of water.

Gravity is of secondary importance in judging the qualities of lubricating oils.

Flash Test.—The flash point of an oil is the lowest temperature at which the vapor arising therefrom ignites without setting fire to the oil itself, when a small test flame is quickly approached near its surface in a test cup and quickly removed. When an oil is used for the lubrication of internal combustion engines and thus exposed to severe heat, it becomes imperative not to allow the flash point drop much below 400 deg. F. This is a guarantee of efficiency and durability. Flash is indicative of an oil's suitability for such use.

Inasmuch as the temperature of the explosion exceeds by several times that of the highest obtainable flash, it is clearly apparent that even 100 deg. difference in the flash of two oils can be of no avail in resisting destruction within the explosion chamber. Below the pistons, however, the operating temperature of piston heads and other parts requires the use of high flash oils for reasons of economy and durability. Automobile oils having a flash point below 400 deg. F. show a very appreciable vaporization loss by way of the breather orofices. This loss increases rapidly with a further drop in flash and increase in crankcase temperature.

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Fire Test.—The fire point of an oil is the lowest temperature at which the oil ignites from its vapor when a small test flame is quickly approached near its surface and quickly removed. Since the fire is always above the flash, the fire value becomes of minor importance when judging fresh oils for use in explosion engines.

After an oil has been used in the crankcase of an engine, coming into contact there with highly heated parts and gases (fresh and spent) escaping from the cylinder, past pistons, it usually becomes contaminated with condensed gasoline and water. It is very probable too that unstable oils "crack" to some extent into light and heavy products.

Carbon Residue Test.—Carbon residue determination consists of distilling a definite quantity of oil in a standard flask, to the end, when a carbon deposit, or residue is left upon the walls of the flask. This is weighed, and the percentage of carbon residue obtained. The percentage of carbon residue relatively high or low, which an oil contains, does not necessarily indicate the amount of carbon deposit which will occur in the combustion chambers of an engine. Carbonization is also materially influenced by the quality of the oil, by its viscosity, and flash, and by the mechanical defects of the engine.

Color Test.—Color values of oils are determined by comparing their colors, by transmitted light, with the colors of standard chromate solutions, or with the colors of glass slides corresponding to these solutions. Color in no way indicates the quality or durability of an oil, neither does it show its suitability for a certain use.

Cold Test.—The chill or cold test of an oil is the lowest temperature at which the oil will pour. This characteristic needs only be taken into consideration because of its effect upon the free circulation of oil through exterior feed pipes, etc., where pressure is not applied. The cold test is in no way indicative of the lubricating or heat resisting qualities of an oil. If an auto-

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motive engine must be exposed to extremely low temperatures in an unheated garage or out of doors, only oils having a cold test corresponding to the exposure temperature should be used.

Viscosity Test.—Many instruments are at present in use in different countries for measuring the relative viscosity or body of lubricating oils. In the United States, the Saybolt and Tagliabue instruments are used almost exclusively by oil refiners and by oil users. The object sought by all instruments, however, is identical in every case. The result of the measurement called viscosity is, with few exceptions, expressed as a number of seconds required for a definite volume of oil under an arbitrary head to flow through a standardized aperture at constant temperature. In other words, viscosity is an empirical expression of the molecular cohesion (internal friction) of fluids. Readings are commonly taken at 100 deg. and 212 deg. F. In referring to the viscosity of an oil, it is essential to state the kind of instrument used. The viscosities referred to in this paper are Saybolt.

Even a novice can readily note the difference between the power and rapidity of acceleration of his engine when using a light or medium oil (180 to 350 seconds) as compared to an extremely heavy oil (2,300) seconds. When oils lighter than 180 seconds are used the horsepower falls off very rapidly until the pistons and bearings finally seize. Fuel consumption reaches its minimum when a light oil of about 180 seconds is used. Oil of this viscosity gives the maximum horsepower obtainable. As the viscosity increases from 180 seconds the fuel consumption increases uniformly with it. With oil below 180 seconds the fuel mounts to its maximum. Both laboratory and service tests on the road demonstrated that the viscosity at which the highest economy of both fuel and oil together with horsepower lies between 300 and 800 seconds. Were it not for the difficulty of a more rapid carbonization (when heavy oils are used) no oil having a viscosity of less than 300 seconds would be recommended. But a practical compromise must be reached; consequently light and

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medium oils (180 to 300 seconds) are regularly specified as being the most fool proof in character and hence best capable of meeting the most widely differing conditions of service.

Evaporation Test.—The rate of evaporation and the characteristics of different oils have a very important bearing on the losses of oil through the breather orifices in the crankcase of the engine. In a practical way this means a decrease or increase in miles per gallon of oil used. The evaporation test is run in many ways in different laboratories, but the results obtained on different oils by any good method are capable of comparison. It may be determined as follows:

Place a weighed amount of oil to be tested in a breaker and heat on an electric plate up to 300 deg. F. maintaining this temperature for a period of from six to ten hours. The oil remaining is then weighed and the percentage of loss by evaporation is calculated from the difference in weight, before and after heating.

Chemical Requisites of Motor Oils.—To obtain maximum lubricating efficiency and durability, it is imperative that engine oils contain the smallest possible quantity of unstable hydrocarbons and no "sulpho" compounds or other impurities which cause rapid decomposition of the oil. The proper methods of making emulsion tests to determine the presence of "sulpho" compounds are as follows:

Fill the bottle one-third full with the oil to be tested. Pour in an equal amount of water, leaving a space of one-third free above the oil and water. Cork and shake the bottle vigorously 30 minutes in a shaking machine (or by hand). Then set it aside for 24 hours. Good oil shows a fine white line of demarcation between the oil and clear water below, indicating the absence of acid compounds. Impure oil mixes permanently with the water, appearing as a curdled mass, floating upon milky water below. The curdled portion is a sort of sulphuric acid soap, and the

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amount of curd shows the quantity of "sulpho" compounds present.

In all types of automobile engines a certain amount of burned gas escapes past the pistons into the crankcase, where water vapor in these products of combustion condenses and settles to the bottom of the oil in the sump. This unfailing source furnishes sufficient water to cause the complete emulsification of that part of the used oil that will emulsify. The tendency to emulsify is naturally much greater during cool weather than during hot weather, for the reason that in summer the heat of the oil in the crank case is sufficient to prevent condensation of the water vapors and to assure their expulsion from the crankcase through the breather pipes.

Thorough draining and cleansing of the crankcase every 500 to 1,000 miles is to be strongly recommended, particularly during the winter. Very frequently the level of the oil in the crankcase remains the same or rises instead of decreasing during the operation of the car over several hundred miles. Some persons conclude, therefore, that their engines are extraordinary in that they actually generate oil rather than consume it. In the end, however, this belief inevitably results in the disaster of an injured engine or burned out bearings and scored cylinders.

Another way to test for acids is to add copper oxide or copper ash to a sample of the oil contained in a glass vessel; acid free oil retains its original color, while if the oil contains acid, it becomes greenish or bluish. This test, however, is not an accurate one, and should not be taken as conclusive evidence as to the acidity of the oil.

Test for Solid Matter.—The presence of solid impurities in an oil may be detected by adding kerosene to a small quantity of the oil, making the mixture quite thin it is then poured through filter paper which will strain out any solid matter that may be present. The paper is then washed with gasoline, leaving it clear unless solid impurities are contained in the oil.

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Durability Test.—Irrespective of the type of lubricating system employed in automobile engines, oil is splashed at every stroke against the underside of the highly heated piston heads. This oil spray cools the piston to some extent, but the heat absorbed by it causes a decomposition to take place in the oil. In this manner the oil within the sump is turned black, and solid black sediment is precipitated. The best lubricants show the greatest resistance to such decomposition and consequently deposit the least amount of sediment.

The laboratory method usually employed to determine sedimentation values is first to make the evaporation test as described previously. The greatly thickened oil is then treated with petroleum ether to separate the resinous matter in the form of a reddish brown precipitate. This is thoroughly washed with petroleum ether, dried, weighed and recorded as the percentage of sediment. The evaporation and sedimentation values thus found are comparable to the service results obtained with the same oil in an engine.

Power Test.—In order to ascertain the lubricating qualities of various oils, the average motorist will find the hill climb test the best suited for this purpose, as few have at their command skill and laboratory equipment capable of making a thoroughly scientific test.

We will assume that a number of oils are to be compared and that a fairly long and steep hill is available for the test. The start should be made in each case at a given place and the speed at the top of the hill recorded as the comparative measure of the oil's friction-resisting qualities. Before the test is made the oil in the engine should be completely drained and the crankcase refilled with kerosene, and run for about 30 seconds to cleanse the interior of the engine. The kerosene is then drained and oil sample #1 poured in. The radiator filler cap should be equipped with a thermometer to show the temperature of the cooling water. This must be the same in each case—say, about 200 deg. F,

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In each test the driving conditions must be uniform and no adjustments of any kind made. After the first test is made, the car is driven back to the starting point, the oil drained, the crankcase again washed with kerosene and the second sample tested as in the case with the first and likewise with the others. Road tests of this kind are the best made between noon and 3 P. M. as the humidity of the air at this time is more uniform. A clear, hot day is to be advised and there should be very little wind. All the tests should be made as quickly as posisble that the atmospheric conditions be the same in each case; humidity and barometric pressure have a pronounced effect upon the power of the engine, due to the carburetor's action.

This same test may be made over a level stretch of road, though the results are liable to be less accurate. After the results have been found we may conclude that the oil used in showing the highest speed affords the greatest power.

Road Test for Sediment.—This is one of the most important tests in determining the oil best adapted for the engine. If the dealer is making the test it is advisable to employ the cars of several customers, as no two persons care for or drive their cars in the same way or under identical circumstances. And, too, the condition of wear in two engines is seldom the same.

The crankcase should be drained and washed out with kerosene, the carbon removed, and valves ground before beginning the test. The milage is then recorded, and the first sample tested under ordinary driving conditions. The test should cover a distance of from 400 to 500 miles. The same kind of oil should be supplied to the engine as needed. At the end of the first test the mileage is recorded and the crankcase drained. This oil should be stirred and a portion of it put into a clear glass bottle and allowed to stand undisturbed for 24 hours. At the end of this time it will be noted that a black sediment has precipitated to the bottom of the bottle. This sediment is com-

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posed of sediment already spoken of and minute particles of the metal parts of the engine worked off during the test. The best oils contain the least amount of sediment. The carbon is again removed, the valves ground, and the other sample tested as in the first case. The percentage of sediment is calculated for each sample drained from the engine at the conclusion of the test.

When the results of all the tests described have been obtained, it may be that several oils are of about the same high grade, and apparently equally suited for our purpose When this is the case we turn to the consideration of price, and in so doing must take into account the oil mileage observed in the road test. In this way it may be that a high priced oil sometimes costs less for a given mileage than a low priced oil. Price, however, should be the last thought, as improper lubrication can do more harm than can be overcome by any amount of oiling, after the damage is done.

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CHAPTER VIII.

GENERAL RADIATION

Purpose of Radiator.—A radiator is a device which holds water or some other liquid, or fluid, and radiates into the air a portion of the heat of the liquid or fluid contained. The cooling water of a motor car radiator absorbs some of the heat of the cylinder walls and, in the radiator, allows this heat to be absorbed by the air. Heat is carried (travels) by three methods; conduction, radiation and convection. A portion of the heat of the power impulse is absorbed by the cylinder walls. It is carried through them by conduction. At the outside of the cylinder walls it radiates into the surrounding water, which carries it away to the radiator, to the outside of the tubes and fins, where it radiates into the air.

There are two methods of circulating the cooling water through the gas engine water jackets and radiator; the force system, which keeps the water in circulation and the thermo-syphon system. The pump used in the force system forces the water from the bottom of the radiator to the inlet connection at the bottom of the water jacket. This force carries it through the jackets to the outlet pipe at the top of the engine where it re-enters the radiator and is again cooled. Although this system works satisfactorily on some cars, it necessitates a complication of moving parts and many water connections. In cold weather the water is circulated at the same rate as on the hottest days. Therefore, the manufacturer has but two courses open to him, viz., he must provide a circulating rate which is a "happy medi-

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um'' between the hot and cold engine, or he must install a thermostat to control the temperature and flow of water. In the former case the thermal efficiency is nearly always too low; in the latter the complication of parts necessary adds to the care and attention required. In any force circulation system some style of pump is required; also gears, shafting, extra piping, gland nuts, packing, grease cups, etc.

The thermo-syphon system permits of a more efficient cooling and a system which is vastly simpler, requires none of the engine's power and is not affected by the speed of the engine. The principle of the natural or thermo-syphon circulation is that hot water is of a lower density than cold water, and will, therefore, seek a higher level than cold water. As the water in the jackets is heated by contact with the combustion chamber walls it rises to the top of the syphon tanks. Here it flows over the tops of the radiator tubes, and enters them to displace the cooler water which is descending. Hot water is lighter than cold water and rises to the top, just as oil rises to the surface when poured into a vessel of water.

Thermo Syphon Efficiency.—Gasoline engines operate most efficiently when the cooling water is just below the boiling point. We have seen how impractible it is to use forced circulation to attain this end. The thermo-syphon system, however, as found on the Model ''T'' engine overcomes the difficulties of the forced system, and maintains as nearly as possible the desired temperature. So as soon as the engine is started the water begins to circulate, due to the heat of the combustion chamber walls. However, at the beginning it is scarcely perceptible; in fact there is very little circulation until the water reaches 180 deg. F. It is obvious that an engine cooled in this way will ''warm up'' to the best working temperature much sooner than one in which cold water is forced around the combustion chamber at a high rate, absorbing much of the expansive energy of the hydro-carbon gases. In hot and cold weather alike, the cooling tempera-

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ture will be nearly the same, operating and mechanical conditions being equal.

The Syphon Tank.—It will be noticed that at the top of radiators of a thermo-syphon system is a tank, often of considerable size. This is known as the syphon tank. It is located at the top of the tubes or cells of the radiator, and is for the twofold purpose of holding water to absorb any steam formed in the jackets and to keep the top of the radiator tubes or coils covered with water. Should the water level fall below this tank the cooling water in the jacket would be sure to boil, as it would have no means of circulation, the radiator would be of no value if circulation were to stop. The syphon tank is placed at the top of the system instead of the bottom for the same reason that the storage tank of a fire protective sprinkler system is placed well up in the air instead of on the ground. A half inch pipe, filled with water to the same height, would furnish equal pressure; but if a few quarts of water were drawn from it the pressure would diminish many pounds. So it is with the syphon tank; the loss of a small quantity has little effect on the cooling system, provided the tank is not completely drained.

Water Passages.—Water jackets, hose, piping, in fact all water passages of the thermo-syphon must be of ample size to facilitate the flow of the cooling water. Also sharp turns should be avoided. It will be noted that on the Ford engine these details have been very carefully worked out.

Types of Radiators.—The two types of radiators used on motor cars are the cellular and the tubular. The former consists of a series of cells sometimes arranged in sets or tiers (this type is known as the honeycomb radiator). The water flows from the top of the radiator down between these cells, where it is cooled by the current of air drawn through them. The cellular radiator is made in a large variety of designs. In some the water flows straight down; in others it zigzags from side to side. This type employs no fins but is complex even in its sim-

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plest form. The water passages are small, hence only a small amount of water is exposed to the air at one time. A natural or thermo-syphon circulating rate is retarded because of the small openings and roundabout course the water follows. The manufacture of such a radiator is complex and expensive. While it can be made substantial it is difficult to repair and weighs more than the tubular type. The small passages are easily clogged, and very hard to clean. The cooling rate of the cellular radiator is usually too high, with a resultant loss of power due to a low temperature cooling water.

The Ford Radiator.—The tubular type of radiator is the simpler of the two. It is light in weight, strongly built, an efficient cooler, and is easily repaired. It permits of an easy circulation of both air and water. Such is the radiator on the Ford Model "T". The use of a large number of small tubes fitted into a series of flat strips of sheet metal (or fins) makes a core which is more substantial and more efficient that the almost obsolete type of large tubes surrounded by helical fins. The top tank and sides of the Ford radiator are covered by a shell of black enameled sheet steel which enhances the appearance of the car, and has a more durable finish than would be possible were the enamel applied directly to the radiator proper. This is simply slipped on and held in place by the two bolts which hold the radiator to the car frame's side members.

Construction of Ford Radiator.—The parts of the Ford radiator are, filler cap, filler cap gasket, filler top tank, top tank front, top tank back, upper header, top tank top re-enforcement angles, splash plate, upper water connection, overflow pipe, overflow pipe straps, hood rod socket, hood rod socket washer, side walls, fins, tubes, support, lower header, bottom tank, bottom tank brackets, lower water connection.

The radiator core or body consists of 95 tubes (1-4 in. in diameter, 17 3-8 in. long, and .005 in. in thickness), 87 fins, radiator support, and the lower header. When the core

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has been assembled it is placed on a conveyor which carries it through an oven at 425 to 450 deg. F. This temperature is sufficient to melt the solder on the various parts of the core, thus automatically soldering them rigidly in place. Both water connection, hood rod socket, and the radiator support are tinned to prevent their rusting when in contact with the water. After the tanks have been assembled and soldered in place on the core, the bottom tank brackets spot-welded to the support, and all small parts put in place, the entire radiator is tested and ready to be installed on the car.

Radiator Efficiency.—We have already seen the need for cooling and also the type of radiator best adapted to the Ford engine. To be efficient a radiator must have not only free passages for air and water, but must provide the proper amount of radiating surface. The fins of the Model "T" radiator present a combined radiating surface of 54.63 sq. ft. The 95 tubes expose to the air an additional area of 8.94 sq. ft. Thus we find that we have a total radiating surface of 63.56 sq. ft. A better comprehension of this area can be had if we consider it as the area of a plat 8 ft. wide and 8 ft. high. All this is accomplished in a radiator core 19 in. long, 2 5-8 in. in breadth and 17 3-8 in. high.

The 95 tubes of the Ford radiator hold 70.58 cu. in. of water, or 17.4% of the water in the entire radiator. Each cubic inch of water in the tubes has a radiating area of 113.6 sq. in. From these figures we can get an idea of the effect caused by one clogged tube. Of the 3 gallons of water in the Ford cooling system 2 gallons is in the radiator; the remainder is in the water jackets of the engine and the two pipes leading to them.

Radiator Troubles.—When a car is in operation, overheating may be detected by boiling water, hot foot pedals, various knocks and pounding noises (usually low pitched) lack of power, etc.

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Causes of Overheating.—The timing of the ignition has a noticeable effect upon the cooling of an engine. It is a well known fact that running an engine with the spark retarded causes overheating. This is because the piston is already part way down in the cylinder when ignition occurs. This means that a considerable part of the cylinder wall is exposed to the flame when it is at its hottest point. It can readily be understood that in this way, after a short time, the cylinder walls have been considerably exposed to unusual heat, causing the cooling water to boil.

Also more gas including more heat units must be admitted into the cylinder to furnish the normal amount of power. This is necessary because the gas is expanded in a larger compartment, and its expansive effect is less than in a small one. From the above we may conclude that it is not economical to run continuously with a retarded spark.

Fuel Mixtures.—Nearly every motorist knows that a rich mixture of gasoline with air causes overheating in the engine. The primary cause of this excessive heat is the large amount of heat units introduced into the cylinder. One fact we must bear in mind is that it takes a certain definite length of time to burn a given amount of fuel; this is true no matter at what speed the motor may be running. If the mixture is rich it takes longer for it to burn, because there is more gasoline in it to be burned; also less oxygen in the mixture to form the combustion. At high speed the spark should occur before the piston has entirely completed its compression stroke. The charge of gas, however, has not been completely ignited before the piston has reached top center, because, as stated before it takes a certain definite length of time to burn a given amount of fuel. Thus the heating effect of a rich mixture is the same as with a late spark. With the mixture very rich it still burns as it leaves the cylinder. This condition results in fouling spark plugs,

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making soot deposits on piston and valves, and sometimes warps valves and valve stems. If the engine could be kept cool under these circumstances these results would not obtain, but because it cannot each makes the others worse.

Condition of Valves.—The valves must be properly ground and seated to insure proper cooling. When they leak the throttle must be opened wider and the mixture in the carburetor made richer in order that the explosion have sufficient force to do the work required. The result is overheating and a waste of fuel due to the rich mixture.

Clogged Muffler.—When the muffler becomes clogged it retards the passage of the exhaust gases from the cylinders out into the air. Because these hot gases cannot escape easily they sometimes lag behind, and a portion may remain in the cylinder even when the exhaust valve closes. This usually results in backfire and often stalls the engine. Overheating is caused by the burnt gases remaining under back pressure too long in the cylinders. Making the mixture richer is of very little help in this case, in fact, it has a detrimental effect as regards cooling.

Pre-Ignition.—By definition this is an ignition before the proper time. It is caused by hot particles of carbon on the top of the piston. These become hot enough to ignite the mixture under compression before the spark occurs at the spark plug. In fact when hot enough it will keep the engine running for a short time when the ignition switch has been shut off. The detrimental effect is loss of power and overheating. The early explosion of the gases results in negative work, or back pressure on the piston. A rich mixture is often made to make the explosions strong enough to do useful work, i. e. to keep the engine working. But the rich mixture together with the long exposure of the cylinder walls to the hot gases make the engine overheat.

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Other causes of overheating are: i. e. low supply of oil or water, broken or loose fan belt, improper angle of fan blades, obstructed air or water passage, dragging transmission bands, heavy carbon deposit, etc.

Cleaning Solution.—Lye solution: into five gallons of water dissolve a half pound of lye, strain through a cloth and pour in radiator, start the engine and let it run about five minutes, then drain the radiator, refill with clean water and start the engine for a few minutes, then draw off water and fill again with clean water.

Soda solution; mix a half pound of washing soda in four gallons of hot water, fill the radiator. If the radiator is very dirty it is a good idea to run the soda solution through several times to remove all the scale.

Cold Weather Precautions.—In winter a water cooled engine must be guarded against freezing, for if water freezes in any part of the system, it will cause the breaking of piping or radiator, or crack a water jacket. While the engine is running the water is kept warm and there is little danger of freezing but when the engine is stopped care must be taken. To prevent the water from freezing an anti-freeze solution should be used, such as denatured alcohol, wood alcohol or glycerine mixed with water.

Anti-Freeze Solutions.—Wood alcohol and water.

10° above zero,	............80% water	20% alcohol
zero,	............75% water	25% alcohol
7° below zero,	............70% water	30% alcohol
22° below zero,	............50% water	50% alcohol

If denatured alcohol is used increase the percentage of alcohol in the above table 15%.

Glycerine and Alcohol.—

30°—15° above zero	to 5° below zero	to 15° below zero
Alcohol 15%	Alcohol 15%	Alcohol 20%

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Glycerine 10%	Glycerine 15%	Glycerine 20%
Water 75%	Water 70%	Water 60%

General Information.—Mixture of solder used in Ford radiator.

Tubes are soldered with	................40% tin	60% lead
Supports are soldered with	..............50% tin	50% lead
Headers are soldered with	..............46% tin	54% lead
Washers are made of	...................50% tin	50% lead
Wire solder is made of	..................46% tin	54% lead

There are 102 holes in the radiator support. The difference between the front and rear of the core is that there is a small hole in the radiator support at the rear on left side.

1916 Model contains	95 tubes 14⅞ in. x ¼ in. x .010 in.
Later Model contains	95 tubes 17⅜ in. x ¼ in. x .010 in.

1916 model contains 74 fins
Later model contains 87 fins
1916 Model holds 2 gals. and 1 pint
Later Model holds 1 gal. and 7½ pints
1916 cooling system holds 3 gals. 1 pint
Later cooling system holds 3 gals.
1916 model contains 6,692 14-25 sq. in. of radiation surface
Later model contains 7,868 7-25 sq. in. of radiation surface
1916 model contains 271 sq. in. on face of core
Later model contains 323 sq. in. on face of core
The later radiator is 2½ in. higher than the 1916 model.

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CHAPTER IX

AUTOMOBILE FUELS.

A fuel is any substance which will burn, producing heat energy which may be utilized as power. It can be seen that both steam engines and internal combustion engines will come under this category, but we will confine ourselves to the latter for very few steam automobiles are in operation today.

In the modern automobile, gasoline is nearly always used, although kerosene is becoming quite common as a source of energy. Other automobile fuels are benzol, a coal tar product, alcohol and certain fixed gases such as acetylene gas and illuminating gas, both natural and artificial. All of these sources of power other than gasoline have both advantages and disadvantages, and in nearly every case the disadvantages are greater than the advantages. This is doubtless due to the fact that the motor car industry has been developed along the line that gasoline is *the* fuel.

The ideal fuel should fulfill several conditions the most important of which are:

1. It should be moderate in price.
2. There should be a minimum of desposit of carbon in the cylinders.
3. It should be volatile enough to start the engine easily.
4. It should be volatile enough to evaporate and mix with the air under ordinary atmospheric conditions.
5. It should have an exhaust fairly free from obnoxious odors.

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Fuel Mixing.—The usual practice is to have the fuel in the form of a vapor, when it is introduced into the engine. When we use a liquid fuel, as we generally do, the fuel must be transformed from a liquid state to a gaseous state, and then mixed with the proper amount of air, so as to form an explosive or inflammable mixture. It is the presence of hydrogen and carbon in the fuel, and oxygen in the air which forms the explosive mixture.

Liquid gasoline will burn quietly and vaporized gasoline will not burn at all. But if gasoline is mixed with air in the proper proportions, a very explosive mixture is formed. When this mixture is heated to a certain temperature it ignites and expands. This drives the piston down the cylinder, which is the first direction of the train of power transmission. The presence of water in the gasoline, and consequently in the gasoline vapor, is rather unsatisfactory for it lowers the temperature of the mixture, and to a certain extent retards the combining of the gases.

Originally this conversion from a liquid to a gaseous state was accomplished by passing the air through the gasoline, and the vapor which arose from the gasoline was carried to the cylinders.

The serious objection to this method was that after a time, the heavier oils which did not evaporate so freely collected in the container, and a point was reached when it was impossible to evaporate enough fuel to run the engine

The Wick Carburetor.—This difficulty was overcome by what is known as the wick carburetor. In this class of carburetor the fuel was raised from a bowl by means of a wick, and the air passing over the wick carried away *all* of the liquid. The chief disadvantage of this type was that the wick "gummed up". And so the automobile engineer had to devise some other and more satisfactory means of supplying the fuel to the firing chamber of the cylinders.

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Function of Carburetor.—Before we take up the carburetor let us define it and consider what a carburetor really does.

A good carburetor should fulfill the following general conditions:

1. It should form a mixture of air and hydro-carbon vapor in fairly constant proportions.
2. It should function to any desired extent.
3. It should perform its duty under the varying conditions of—

   1—Atmospheric or suction pressure.
   2—Speed
   3—Temperature
   4—Power

The Jet Spray Type.—The ultimate form of the carburetor, that is to say the form in use today, is known as the jet spray type.

The fuel in a liquid form passes from the fuel supply tank to carburetor bowl which is in reality a small auxiliary tank, where the level is more or less constantly maintained by means of a float which operates a supply valve by means of one, two, or even more levers. In some types this valve is operated in the same manner as the ordinary valve in a toilet tank. This float may be made of any substance which is lighter than gasoline, i. e., cork or sheet brass soldered so as to make an air tight float. From this bowl, or float chamber as it is often called, the gasoline is sprayed by means of a needle valve into what is known as a mixing chamber. Here air is also admitted and thus the mixture of air and hydro-carbon vapor is effected. The passage of the air and gasoline vapor through this mixing chamber into the firing chamber of the cylinder is caused by the suction from the piston as it descends in the cylinder. There is a butterfly valve which may be adjusted to regulate the supply of air admitted into the mixing chamber.

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When starting the engine it is common practice to close this opening and then a mixture richer in gasoline vapor is introduced into the engine. This will fire more easily providing it does not get too rich, because an engine can very easily be choked by shooting pure gasoline vapor into it.

Choking.—The reason for "tickling the carburetor," as it is called, is that the fuel does not evaporate quickly enough to impregnate the air with vapor, while the engine is standing still. By agitating the float a certain amount of fuel issues forth from the jet and the more readily evaporates into air. In case of the Ford car the standard Holley carburetor has no provision for "tickling". What does happen is that the air supply is diminished by means of the priming rod which controls the butterfly valve. As the piston descends the cylinder there is a partial vacuum formed which causes the gasoline to issue forth into the evaporation chamber; this presents a greater surface to the air, and so the mixture of air and gasoline vapor is enriched.

Air Valve Compensation.—If a carburetor is adjusted for an engine to run at a certain speed and the engine is run at a greater speed, it is found that the mixture becomes richer as the speed increases. This is due to the fact that through the adjusted opening for the air into the mixing chamber only a limited amount of air can pass. Therefore, a partial vacuum is formed, which causes the gasoline to spray forth faster and in greater proportions than the air. A valve with a spring is attached in place on the mixing chamber or on the pipe leading thereto. When the air pressure within this chamber is diminished, or a partial vacuum is formed, the pressure from the outside air forces this valve open allowing air to enter the chamber until the pressure is normal again. This is known as the air valve compensation.

Sweating.—When a substance is changed from a liquid to a gaseous state, heat is required to bring about this change.

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Under certain conditions the formation of ice on the outside of the carburetor may be observed. Also moisture may collect on the outside of the carburetor. This is known as "sweating". This is due to the fact that the carburetor is too small for the amount of gasoline vaporized, too much heat is required for this change, and the carburetor cools off faster than the outside air can warm it up. The heat required to change the fuel to a gas is called "the latent heat of vaporization". This principle is utilized in the manufacture of artificial ice, and also in refrigerating systems which do not require ice. If no provision be made for this phenomenon then the temperature of the mixture of vapor and air will be lowered, which condition will retard both vaporization and ignition.

This condition may be overcome in several ways, the most important of which are as follows:

1. By heating the carburetor with warm water from the cylinder water jacket.

2. By heating the carburetor with a portion of the exhaust gases, and

3. By heating the air before it passes into the mixing chamber. Care must be taken, however, not to supply too much heat to the carburetor, for if too much heat be supplied, then the air will take up more gasoline vapor, and thus destroy the proportion of air and vapor. Therefore only sufficient heat to supply latent heat of vaporization should be supplied.

Location of Jet and Bowl.—The jet and bowl of the carburetor should be located as closely together as possible so that the grade of the road will not cause the level of the fuel in the two places to vary a great deal. The float chamber should be on the forward side of the jet so that when the car is ascending a hill and the engine is revolving faster, the fuel will tend to spray forth faster; and when descending a hill the mixture may weaken without risk of stopping the engine.

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The intake manifold should be so arranged and designed that all of the cylinders will draw their supply from the same volume of piping. There should be no sharp bends, but rather as large curves as practical. Y's should be used rather than T's. Inspection of the different intake manifolds will show how these ideas are worked out. But to get back to our subject of fuels.

Liquid Fuels.—The most common of the liquid fuels is gasoline, or petrol. Gasoline is a derivative of petroleum. All of the recent investigations seem to show that petroleum is formed by the decomposition of organic matter of both animal and vegetable origin. The theory is that petroleum was formed by the action of heat and pressure on the organic remains of the earth, such as trees, leaves, animals, etc. The composition of the various petroleums is not exactly the same. They may vary considerably, but if they be distilled and the vapors condensed or cooled practically the same substances will be obtained, although they may be in different proportions. Some of these products are gasoline, kerosene, paraffin wax, lubricating oils and the heavy grease. In the first place the crude petroleum was refined for the kerosene, but of late years gasoline has become the chief product and kerosene has become a by-product.

We here in this country are accustomed to thinking of gasoline as the only engine fuel, and of petroleum as the chief source; but this is an error. As far back as 1661 wood was heated in a closed vessel, and the tar was extracted. At that time the more volatile portions were allowed to escape—this included gasoline. This was the first source of tar. By this method, in Norway, pine was treated, and both tar and pitch were obtained commercially in the 17th century. A little later the volatile parts were collected and stored in tanks. This was the beginning of the manufacture of illuminating gas. After a time the heavier oils and greases were also extracted. Peat and also the bituminous shales were used as a raw material for

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the production of illuminating gas, paraffin wax, lubricating oils, etc.

This bituminous shale was treated in quite the same way as wood or peat. It was heated in a closed container to about 2,000 deg. F. This drove off the hydro-carbon contents of the rocks which when cooled yielded the oils of varidus densities. Petrol among these.

Benzol as a Fuel.—Benzol is a coal tar derivative. Coal is heated in a closed retort, and coke is thus made. A heavy black substance is also produced. This is the common coal tar, which we in this country use for roofing, paving, waterproofing, etc. If this be distilled or boiled and the gases collected as they arise, a multitude of substances may be formed from this coal tar. Benzol is among this legion.

Benzol will give very satisfactory results in the modern automobile motor, and requires little or no change in equipment from that used for gasoline. Also a higher mileage is obtained from the use of benzol.

Kerosene as a Fuel.—There has been considerable experimenting in the last few years with kerosene, and the results have been very satisfactory. Kerosene has a lower specific gravity than gasoline, and a lower boiling point and so there is quite some difficulty in starting the engine with kerosene alone. This difficulty is overcome by having an auxiliary tank of gasoline for starting purposes only. When the engine is once started and warmed up then the kerosene can be used as fuel quite successfully. Another objection to this fuel is that it leaves a carbon deposit in the cylinder, after the explosion. This is due to the fact that kerosene does not burn as quickly as gasoline. One of the advantages of this source of power is the moderate cost. The chief disadvantage seems to be that it requires a higher temperature to evaporate the fuel, and an attendant higher temperature to ignite it; and that it leaves carbon deposit in the cylinder. Also it is not possible to

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operate the engine with as much compression. There is a loss of from 15% to 25% in the power that can be derived from an engine of the same size.

Alcohol as a Fuel.—Alcohol can be extracted from any vegetable matter containing starch or sugar. Alcohol can be produced from beets, potatoes, cereal grains, sugar cane, etc. The supply is practically world wide and well nigh inexhaustible. Alcohol will not burn as rapidly as gasoline, the mixture of alcohol vapor and air must be compressed more highly than in the case of gasoline vapor and air. It has been noted that an engine running on alcohol operates with less noise and vibration than with gasoline. This is due to the fact that alcohol burns more slowly than gasoline; and so that the power is imparted not with a sudden sharp impact but it is applied for some distance down the piston stroke. This gives a more uniform turning effort on the crankshaft, and so tends towards smoother operation of the vehicle. In the case of air cooled motors alcohol can be used quite well, for due to its higher ignition point, the engine can be operated at a higher temperature. One of the chief reasons why an air cooled gasoline engine is not entirely successful is that when the engine gets quite hot there is danger of pre-ignition. At slow speeds there is not the consumption of alcohol that there would be of gasoline under like conditions. Excepting at low speed there are no obnoxious odors or poisonous gases from the exhaust with alcohol. Alcohol may be mixed with benzol, the coal tar product mentioned before and quite satisfactory results obtained. At the present time the chief disadvantage of alcohol seems to be that it is quite expensive; that a heavier engine is required and that the vaporizing point and consequently the firing points are higher than that of gasoline.

Thus far we have considered only liquid fuels. But there has been considerable experimenting with fixed gases, such as acetylene gas, illuminating gas, etc.

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Illuminating Gas as a Fuel.—In the last few years experiments with illuminating gas as a source of energy for motor cars have been tried and have been found fairly successful. The gas is stored in tanks which are carried on the car either under the seat, in the running boards or attached to chassis in the rear. With this fuel no carburetor is necessary, only a mixing chamber or mixing valve, which will blend the gas and air in the proper proportions. However, this proposition is only in the experimental stage and so no very accurate estimate of its possibilities can be made.

Acetylene Gas as a Fuel.—Acetylene gas has been proposed quite frequently as a source of power, but commercially this fuel has not been an unqualified success. If the fuel be carried in tanks the cost is too great; and if the gas be generated as it is needed and used it is too inconvenient to recommend itself to the average motorist. When acetylene gas ignites it does so very quickly and thus generates a violent explosion. This would give a snappy action to the engine, but, the power would be applied more at the start of the piston stroke than in the case of gasoline. In conjunction with alcohol, however, acetylene has been used with a measure of success. The alcohol, which has a slow rate of burning, tends to slacken up the speed with which the acetylene burns. Also the difficulty experienced in starting the engine with alcohol is overcome for by feeding a greater quantity of acetylene into the firing chamber of the cylinder we get a mixture which will explode when the engine is cold.

There is a method of combining these two fuels which is patented in the United States Patent Office, which works out something as follows:

An ordinary carburetor atomizes the alcohol, and the mixture of air and alcohol passes into a chamber in which there is a bed of calcium chloride, through which it is drawn by the suction from the engine. Denatured alcohol always contains

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water, which, as it passes over the carbide, generates acetylene gas. The water, which under ordinary conditions is an objectionable constituent, now becomes necessary, in fact about 15% more water is usually added, and the heat evolved in the production of acetylene gas is usefully employed in atomizing the alcohol. The resulting gas is called "Alkeethine". This then passes into the engine and is fired in the same manner as a mixture of gasoline vapor and air.

"If a variation in the rapidity of explosion is desired, the amount of water added to the carbide is increased or decreased, according to whether it is desired to enrich or impoverish the mixture."

The inventor of this process claims to have gotten perfect satisfaction, but, inasmuch as he invented this process some ten years ago and it has not been used to any great extent as yet, it has not been entirely successful from a commercial point of view.

Thus it can be seen that although there have been many fuels which have rivaled gasoline, none have been entirely successful, and each one has one or more drawbacks. This may be due to the fact, however, that the motor car industry has been developed along the line, and with the idea that gasoline is *the* fuel.

The Carburetion System on the Ford Car.—The model "T" car is equipped with one of the simplest of all carburetion systems. The fact that it is simple does not necessarily mean it is not of careful design. In order that the engine develop the most power the carburetor must be in perfect repair and adjustment at all times.

Careful study of the following detailed instructions will assist the repairman to a better understanding of each part and its function.

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Principal Parts Of The Ford Carburetor (Holley Model G) And Their Purposes:

1. *Float chamber or bowl*:
   (a) To keep a supply of gasoline at the proper height to feed the spray nozzle. Has the following parts:
   (b) Cork float, rises and falls with the gasoline level. It operates the—
   (c) Inlet needle valve, which allows gasoline to enter as float goes down, and as float rises shuts it off when it has

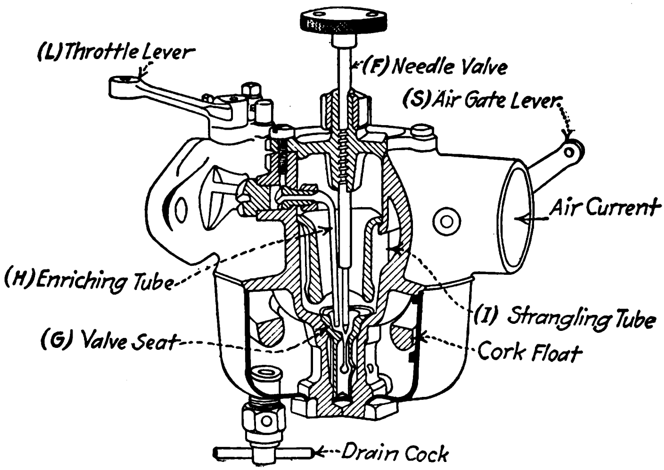

Fig. 22.—The Holley "Model G" Carburetor

reached proper level, 1-16 to 1-8 in. below top of spray nozzle.

2. *Spray nozzle.*—The gasoline passes from the float chamber to the spray nozzle, where it is drawn out in the form of spray by suction from the engine. The hole in the spray nozzle is drilled with a No. 52 drill. This hole is 1-16 in. long, the lower 1-32 in. is straight while the upper 1-32 in. is tapered on a thirty degree angle.

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3. *Spray needle.*—A hand adjustment to regulate the quantity of gasoline passing through spray needle. This is to give the proper mixture of gasoline and air in order that the engine may develop its greatest power. The needle is cut on a thirty degree angle to conform with the angle on the nozzle seat. Points are made of Mokel metal which contains about seventy per cent. nickel steel.

4. *Mixing chamber.*—Surrounds the spray nozzle where air and fuel mix together, with a moving column of air to draw out the gasoline.

5. *Primary air inlet* where set air supply enters carburetor.

6. *Choke valve on primary inlet,* assists in priming. In normal position this valve is wide open, being held in position by a coil spring inside the hub of the lever with the lower arm of the lever up against the stop pin on the mixing chamber. The driver closes the valve while the engine is being cranked. This makes a strong suction on the spray nozzle drawing out the gasoline necessary to start the engine.

7. *Strangling type,* the part where the air passage narrows around the spray nozzle increasing the air velocity and suction on spray needle.

8. *Low speed tube,* inside of strangling tube, used to draw a rich mixture of gas into cylinders when starting car, and when idling.

9. *Overflow hole,* at the bottom of the mixing chamber, lets out surplus gasoline after priming.

10. *Throttle valve,* is used to control quantity of mixture going to engine. As throttle is opened, more mixture is admitted to cylinders, giving stronger explosions and so causing the engine to increase speed. Idling adjustment screw, or throttle stop screw, is a small screw that holds the throttle partly open. It prevents throttle from closing completely and stalling engine.

Path Followed by Gasoline.—(Gravity system) From tank to sediment bulb, to fuel pipe, to inlet needle valve, to float

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chamber, to spray nozzle where it mixes with air in the mixing chamber, past throttle, through inlet manifold and inlet valve into cylinder.

Methods Used to Prime Carburetor.—Or give more gasoline for starting:

(a) By choke valve; to use, close valve and crank engine. The suction draws gasoline out of the nozzle cup through low speed tube into cylinders.

(b) A device on dash to open spray nozzle while engine is being cranked. Priming is necessary as it enables one to draw a rich mixture into the combustion chamber making it easier to start. Ordinary cranking without using the choke valve will not draw out enough gasoline to make an explosive mixture unless the engine is already well warmed up.

Preparatory Rules for Adjusting a Carburetor.—

1. See that compression is all right.
2. See that timing and spark are all right.
3. See that there are no air leaks around the intake manifold.
4. See that a full clear stream of gasoline flows from the tank to the carburetor.
5. Allow the engine to warm up.

Adjustment of the Ford (Holley Model G) Carburetor.—The Holley, being an automatic float feed type carburetor, having no weights, springs or other moving parts, has only one adjustment for quality of mixture—the spray needle valve which also controls the low speed or idling.

Open the needle valve about 7-8 of a turn, though cases have occurred in which 3-4 of a turn was satisfactory, and on the other extreme 1 1-8 turn was necessary.

Instructions for Adjusting.—

1. Loosen adjusting needle locknut until needle turns easily.
2. Screw needle clockwise until it touches the seat (use light pressure).

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3. Turn needle counter-clockwise about 7-8 to 1 turn.

4. Tighten locknut sufficient so that needle can be turned from dash, by adjusting rod and yet be tight.

5. Start engine, cutting off air supply while cranking by pulling choker.

6. Allow engine to warm up for a few minutes.

7. Adjust by means of turning the needle, never more than 1-16 turn at one time. If the operation of the engine indicates a lean setting, turn adjusting rod counter-clockwise, or to the left; but if the mixture is too rich turn needle clockwise, or to the right.

8. When the quality of the mixture is determined as above, the idling speed of the engine can be set by means of the adjusting screw mounted on the throttle lever, usually called the throttle idling stop screw.

Incorrect Adjustment.—The following points indicate an incorrect setting of the needle valve adjustment.

A—A lean mixture.

1. Engine hard to start.
2. Engine fires back through carburetor, when opening the throttle quickly.
3. Engine knocks when opening throttle, similar to carbon or spark knock.
4. Engine will not idle or run evenly.

To Correct.—Turn adjusting rod counter-clockwise. Give engine more gas. Engine will pick up speed and run evenly.

B—A rich mixture.

1. Spark plugs foul quickly.
2. Exhaust gas causes eyes to smart.
3. Black smoke from the muffler.
4. Engine operation uneven or sluggish.
5. Difficult for engine to pick up speed.
6. Gasoline mileage low.
7. Muffler explosions.

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8. Carbon deposit on pistons and cylinder head.

To Correct.—Turn adjusting rod clockwise giving the engine less gas.

Correct Adjustment.—

1. Close throttle—with spark between half advance and fully retarded positions, engine should run evenly.

2. Car should run 6 to 7 miles per hour smoothly on closed throttle.

3. Run ¼ to ½ miles at 12 to 13 miles per hour—engine should run evenly.

4. With car running 7 to 8 miles per hour, open throttle wide quickly, car should accelerate smoothly.

5. At all other speeds running should be smooth with good acceleration.

Effects on Different Mixtures.—

1. A lean mixture, shown by popping back at carburetor, weak power.

2. A rich mixture, indicated by a strong odor of gasoline at the exhaust, black smoke at the exhaust, jerky running engine and overheating.

3. Correct mixture, will be indicated by proper acceleration of the engine at all speeds and all throttle positions.

Backfire in Carburetor.—May be caused by:

1. Lean mixture, needle valve closed too far. Leak around inlet manifold, clogged fuel pipe or dirty strainer, water in the carburetor.

2. Leaky intake valve, broken inlet valve spring.

3. Commutator or timer short-circuited.

To Distinguish Carburetor Trouble.—From ignition trouble, remove a couple of spark plugs, prime cylinders and see if engine will run. If the engine will not run the ignition is at fault. If the engine runs and stops the carburetor is at fault. Very often we can tell by the way the engine stopped. If the engine stopped suddenly as if the switch were turned off, igni-

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tion trouble is indicated. If engine grew weaker, missed a few explosions and stopped, carburetor trouble is indicated. Sometimes it backfires just before stopping, showing a weak mixture.

Defective Carburetor.—A classified list of carburetor troubles:

1. No gasoline in tank.
2. Valve closed at tank.
3. Clogged strainer in sediment bulb.
4. Clogged fuel pipe.

Indication.—Engine stops. Test—Open drain plug on carburetor. No drip. Remedy, trace out trouble step by step beginning at gasoline tank. Clogged fuel pipe or strainer gives this characteristic sympton. Engine stops, but may be started after a minute or so only to stop again. As this trouble comes on the engine does not respond readily to the throttle, sometimes popping back at carburetor. Remove and clean strainer or clean out fuel pipe.

5. Inlet needle valve worn.
6. Dirt in inlet needle valve.
7. Heavy float (cork float saturated with gasoline.)
8. Float caught (jar it).

Indication—Constant drip from carburetor. Test: Shut off gasoline and drain carburetor. Then close drain plug and open supply line. If the drip continues it will be necessary to replace needle or float.

9. Water in carburetor.

Indication.—Engine misses explosions or stops. Test: Draw off some on hand. Gasoline wets hand water is repelled. Remedy, drain off all water.

10. Spray needle out of adjustment.

Indication.—Rich or lean mixture. Test: Change adjustment slightly, or inspect to see if it has been moved.

11. Leaks around inlet manifold. Joints open; allows dirt to enter.

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Indication.—Engine loses power, weak mixture, sometimes a whistling sound. Test: Squirt oil around joints; oil is sucked in at leak. Squirt gasoline around joints; engine picks up speed when leak is found. Remedy: Tighten up bolts or replace gasket.

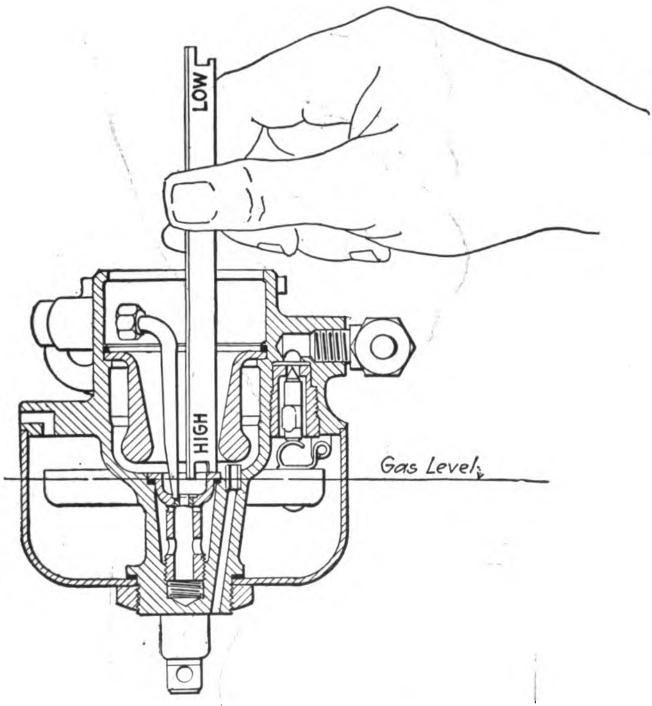

Fig. 23.—Gauging High Level

12. Cold engine: refuses to start because gasoline does not vaporize readily when chilled. Warm up carburetor and inlet manifold with hot water. Fill cooling system with hot water.

To remove Carburetor from Engine.—

1. Shut off valve at gasoline tank; drain carburetor.

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2. Disconnect gasoline line from carburetor.

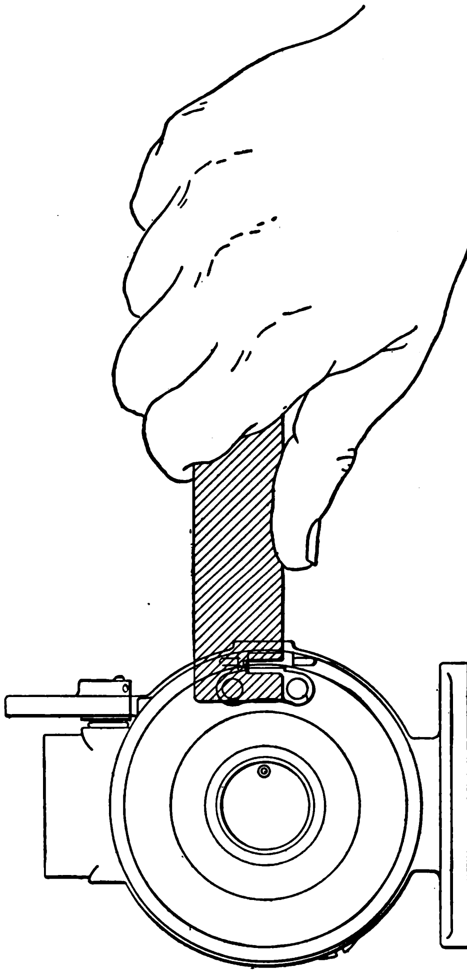

Fig. 24.—Adjusting Float

3. Remove hot air pipe from air intake.

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4. Disconnect wire from choke valve lever.

5. Remove throttle rod from head of spray needle.

6. Remove bolts holding carburetor to intake manifold and save gasket.

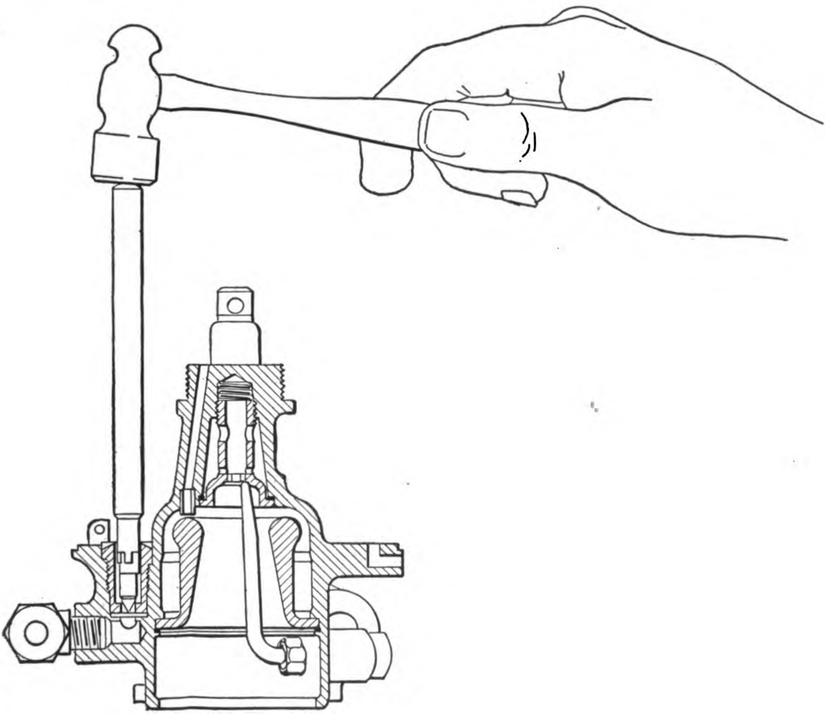

Fig. 25.—Seating Inlet Needle

Instruction for Service Men.—To follow in repairing carburetors.

The Fuel Level. It is very important that the fuel level be at its proper height in the nozzle, to obtain the best general operation and particularly the idling. The fuel should stand

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1-16 to 1-8 in. below rim of cup. To test fuel level make a gauge of a flat piece of stock 5-16 in. wide, 1-8 in. thick and 6 in. long. File slot in each end 3-16 in. wide and 3-16 inch deep, which leaves two points 1-16 inch thick at each end of the game; then file one point at each end 1-16 in. shorter than the other on one end and 1-8 in. shorter than the other on the other end. When testing level have the short point of gauge touch the top of the cup at one side between wrench lugs; hold gauge vertically, fuel will touch the long point when low level end of gauge is used, and may not touch, or should just touch long point when high level end of gauge is used. To set fuel level, see that float measures 1-2 in. from machined flange on mixing chamber to float. Hinge hole in chamber should measure 7-32 in. from center of hole to flange, gives float proper position and controls levels. Raising or lowering float is obtained by bending float lever up or down. Always bend part of float lever on which inlet needle rests. See that float is centered about mixing chamber stem so float will not strike bowl or mixing chamber.

The Inlet Needle and Seat.—Inlet needle seat must be screwed on gasket firmly. Inlet needle must not have scratches or ridges on it. Owing to triangular shape of needle body and shoulders which guide it the needle seat walls and screw driven slots must be free of butts and ridges. All needles taken apart should have sharp edge on the three shoulders rounded with a file making a 1-32 in. radius. The seat will prevent needle from sticking ,and carburetor flooding. To test tightness of inlet needle, turn carburetor upside down, and suck on elbow same as you would on small bottle. Lips should stick to elbow. If inlet needle is defective, same can be unscrewed and new one substituted. The Kingston seat is not interchangeable, with this carburetor on account of having a coarser thread.

The Spray Nozzle.—Spray nozzle is screwed down against white fibre gasket in order to prevent gasoline leakeage around

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same. Nozzle hole is drilled with a #52 drill, and should not be changed under any conditions. Length of hole 1-16 in. upper half or 1-32 in. has 30 deg. taper to conform with

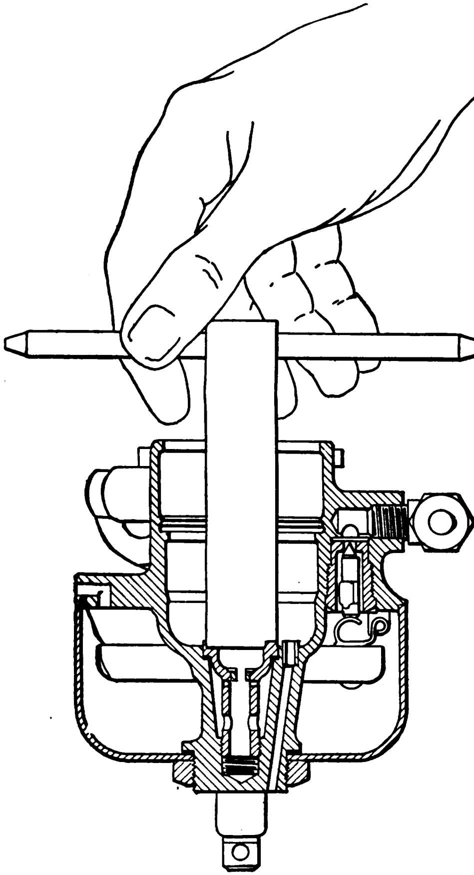

Fig. 26.—Installing Spray Nozzle

taper on spray needle seat. If taper is enlarged or not concentric, replace nozzle. The four #52 holes in the stem of nozzle

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are air holes, which are fed by #52 air hole in mixing chamber, when fuel level lowers in fuel chamber. This allows air to enter with fuel which allows better compensation through intermediate range.

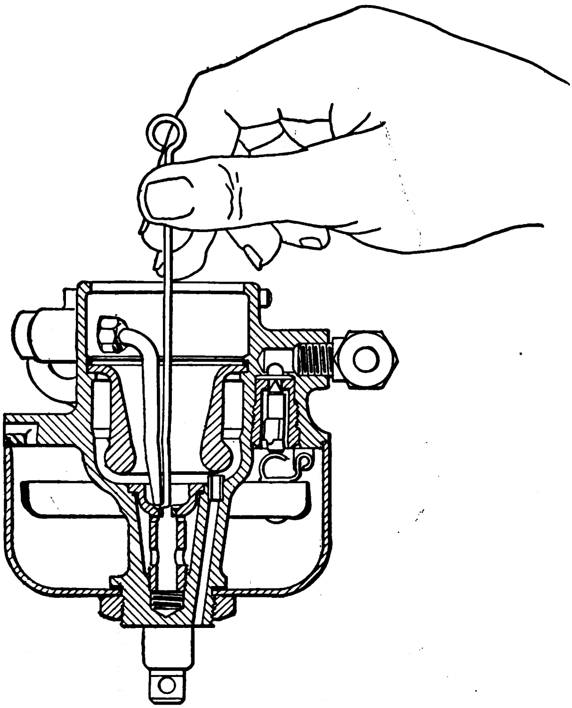

Fig. 27.—Gauging Clearance Under Low Speed Tube

The Spray Needle.—Spray needle must be true and have thirty degree taper, and tapered points must not have any grooves in same, which are caused by screwing needle too hard against nozzle seat.

The Strangling Tube.—Owing to heavier grades of fuel, the carburetor has been equipped with a 23-32 inch choke. This

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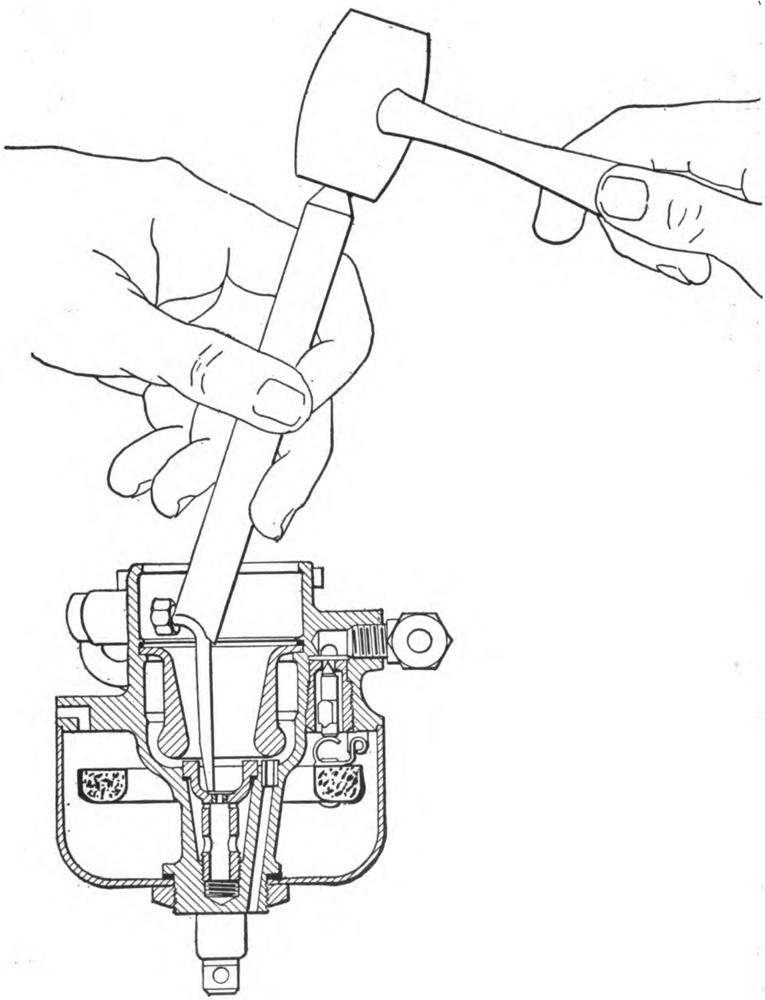

Fig. 28.—Setting Low Speed Tube

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raises the velocity which breaks up the fuel, and gives better operation. All 13-16 in. chokes should be replaced by above size. Clearance under choke should be .125 to .140 in.

Low Speed Tube.—The low speed is used to obtain idling. End of the tube must extend to the bottom of cup in nozzle with .001 in. to .018 in. clearance on side towards nozzle hole. Tube should be held against shoulder in bottom of cup when nut is tightened in order to prevent spray nozzle from striking same. End of tube is flattened and slot should be 1-16 in. wide.

Low Speed Hole in Mixing Chamber.—When throttle plate is set straight across outlet hole, the low speed hole should extend ahead of plate .022 to .038 in. If hole is too far back, a small cape chisel, or small round file, can be used to bring hole forward. Do not use chisel until you have scribed the proper distance.

The Throttle Plate.—The throttle plate should be as near as possible the size of the outlet hole. This gives best idling and economy. If the plate has more than .006 in. clearance more fuel is needed for idling, which will be wasted at higher speeds. If plate is undersize same can be peined around edge to bring to size required. When there is .003 to .006 in. clearance, the same should be on same side as low speed hole. This is done by inserting shim between plate and outlet hole, when rivet holes in plate are being drilled.

Air Hole in Mixing Chamber.—The #52 drilled hole in mixing chamber is used to feed the four air holes in nozzle. The fuel level is above this hole when carburetor is not in action or when idling. This is uncovered when car reaches speed above ten miles an hour, and if not properly located, mixture will be very rich 16 to 18 MPH. From center of hole to nozzle seat in mixing chamber should measure 1-16 in.

Overflow Hole in Mixing Chamber.—This drain hole runs from bottom of mixing chamber stem to the inside of strangle

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tube chamber and comes out at side of nozzle flange; this must always be kept open.

Vent Hole.—Vent hole is on side of carburetor opposite inlet elbow. Choke plate should be closed in order to start engine in cold weather.

Questions and Answers On The Ford Carburetor

Q. What is gasoline?

A. Gasoline is a chemical compound of carbon and hydrogen.

Q. What is a carburetor? What makes a carburetor leak?

A. A carburetor is a mechanical device for vaporizing gasoline and mixing the resulting gas with air in the proper proportions for the varying engine speeds. Improper float adjustment, soaked float and improper seating of the float needle caused by foreign matter such as sand being lodged between needle and seat.

Q. What amount of gasoline to air by weight gives a perfect combustible mixture?

A. One part of gas to from ten to seventeen parts of air with fourteen parts air an average gives a perfect combustible mixture.

Q. What regulates the flow of gasoline into the carburetor from the tank line and how?

A. The float regulates the flow of gasoline into the carburetor by either raising or lowering, according to the amount of gasoline in the bowl, which causes the lever attached to the float to drop or raise which in turn opens or closes the float valve.

Q. Why is a successful kerosene carburetor so much to be desired?

A. Owing to cheapness and more even pulling power of kerosene a practical kerosene carburetor is much to be desired.

Q. How is the float chamber located on Ford Carburetors and what advantage is derived thereby?

A. The float chamber on Ford carburetors is located at the extreme bottom of carburetor. This makes repair on float, etc. easy.

Q. Why do Ford carburetors give such good mixtures for starting when cold?

A. The auxiliary mixing chamber on Ford carburetors gives a good rich mixture when starting.

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Q. Why is an intake air heater desirable?

A. A preheater or intake air heater is desirable as it delivers a warm air to the carburetor which causes the gasoline to vaporize more rapidly.

Q. How many operating adjustments on a Ford carburetor and where placed?

A. The Ford carburetor has one operating adjustment, the needle valve.

Q. How is carburetor adjusted when too far out of adjustment to operate?

A. When carburetor is too far out of adjustment to operate loosen the mixing chamber cover lock nut and turn needle until it seats, next turn needle up two turns for use until motor has warmed up then the correct adjustment may be determined.

Q. What indicates a wrong mixture?

A. Popping in the carburetor, backfiring in the muffler, black smoke, motor will not accelerate properly are indications of wrong mixtures.

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CHAPTER X

ELECTRICAL PRINCIPLES AS APPLIED TO THE FORD CAR.

Introduction.—The electrical equipment on the Ford car is something of a mystery to the majority of mechanics,—few of them understanding the fundamental principles of electricity. The purpose of this article is to explain in detail a few of the simple rules governing its action. Only by careful study of the following and by committing to memory the few simple rules and laws given here, can the mechanic hope to secure a foundation upon which to build his future knowledge of the electrical equipment on the Ford car.

Electricity.—Electricity is a form of power or energy of which little is known. What we need to know is what it will do. In order to get any benefit or use from electricity we must put it in motion, because, if not in motion it is of no practical value. There is a force which causes electricity to be put in motion known as *Electro-Motive-Force* or *Voltage.*

When we have an electrical pressure and the circuit is closed between the positive and negative of the machine or battery, a current will flow. The term or name of this unit of current flow is the *Ampere.* The amount of current that will flow depends upon the voltage and the resistance offered by the line. The resistance of a line depends upon four things, i. e., the material used (copper is most practical), the diameter of the conductor, the length of the conductor, and the temperature.

The name of this term or unit or resistance is the OHM. Electricity can produce power and is capable of doing work. The name of the unit of power is the Watt. In general use of electricity the four terms mentioned above are all that are necessary

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for the mechanic to know. Because of the condenser in the coil unit it is necessary to use or explain two or more units which are the *Farad* and *Coulomb.*

The *Farad,* is the unit of capacity which applies to the condenser itself it being capable of holding or storing electricity.

The *Coulomb,* is the unit of quantity or volume of electricity which is stored in the condenser. The following is a formula for finding the quantity of the unknown terms when the others are given.

Voltage or I—current or ampere. R=resistance or ohms
Pressure or W—watts
Potential

One volt of pressure will force one ampere of current through one ohm of resistance, and in doing so one watt of power is produced.

One ampere flowing for one second is one coulomb of electricity.

One ampere of current flowing for one second can be stored in a condenser having a capacity of one farad. In other words, a condenser with one farad capacity will hold one coulomb of electricity.

$$E = I \times R \text{ or } \left\} \begin{array}{l} \text{amperes} \times \text{ohms} = \text{volts} \\ 3 \times 2 = 6 \end{array} \right.$$

$$I = \frac{E}{R} \text{ or } \left\} \begin{array}{l} \text{Volts : ohms} = \text{amperes} \\ 6 : 2 = 3 \end{array} \right.$$

$$R = \frac{E}{I} \text{ or } \left\} \begin{array}{l} \text{volts : amperes} = \text{ohms} \\ 6 : 3 = 2 \end{array} \right.$$

$$W = E \times I \text{ or } \left\} \begin{array}{l} \text{volts} \times \text{amperes} = \text{watts} \\ 6 \times 3 = 18 \\ 110 \times \tfrac{1}{2} = 55 \\ 110 \times 6.7818 = 746 \end{array} \right.$$

746 watts=1 electrical horse power.

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Conductors.—All metals are conductors of electricity. Some however are much better than others. The metals are classified as to their resistance; the one having the least resistance being the best conductor. Silver has the least resistance, but, its scarcity and expense makes it impractical. Copper being next to silver in conductivity, is much cheaper and more plentiful. Therefore copper is almost universally used as an electrical conductor.

Insulation.—Electricity is conducted from its source which is the generator or battery, to the lamps and other pieces of electrical equipment, through a copper wire called the *Lead.* After the current has passed through the lamps or coil it is connected to the frame of the car and returns to the generator through the metal of the car. Electricity will flow through the path of least resistance, therefore, if the bare wire comes in contact with the frame of the car it will return to its source without doing the work intended because the frame would have less resistance than the filament of the lamps, or the wire in the coil. It is because of this that the wires are covered with rubber or cloth called insulation.

Ground and Short.—In the instance cited above regarding the wire coming in contact with the frame before it reached the lamp, it will not go through the lamp but will return to the battery or generator through the metal of the car. This is called a ground, but it is also a short circuit. If the wire does not touch the metal of the car, the current will pass through the lamp and cause the filament to be heated to incandescence, pass into the frame and return to the battery or generator. This is also a ground connection, but it is an intentional ground and is not a short.

If the different wires or layers of wires in the magneto field coil, the primary coil or secondary coil in the coil unit, come in contact with each other, the current will not go all the way through the coil. This is a short circuit. Another example

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of ground and short is in the starter and generator armatures, when the coils come in contact with the core it is said to be a ground, but if two or more wires come in contact with each other it is a short circuit.

How Electricity is Produced.—There are two kinds of electricity,—Static and Dynamic.

Static electricity is produced by friction and travels along the surface of the conductor. An example of static electricity is when a cat's back is stroked vigorously in the wrong direction with a rubber comb, sparks will be produced which may be seen if the room is in darkness. Lightning is also of the static form. This form of electricity is not used in automobile work.

Dynamic electricity is produced by moving a conductor across a magnetic field. In other words, in order to produce an Electro-Motive-Force three things are necessary: (1) a magnetic field, (2) a coil of wire, (3) speed and movement. For example, the Ford magneto. (1) the sixteen permanent magnets produce the magnetic field, (2) the sixteen coils on the field coil frame of 25 turns each, (3) the speed with which the flywheel is revolved.

When the engine is stopped no current is produced. We have the magnetic field, and the number of turns of coil, but no movement. When the flywheel is turned slowly we have the magnetic field, turns of coil, and movement, but not enough speed. This method of producing electricity is by induction, which will be explained later.

Primary and Secondary.—The term primary is used in reference to the current coming from the generator or battery. It may be high or low tension.

The term secondary is used when referring to an induced current, or one which is stepped up or stepped down from a primary current.

On the Ford system the primary current has a voltage of from 6 to 24 volts, and by sending it through an induction

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coil it is stepped up from eight thousand to twenty thousand volts in the secondary. In this case the primary is the low voltage.

In cross country power transmission it is opposite, because in that case the primary is the high tension and it is necessary to step it down to the secondary.

Low tension is low voltage. High tension is high voltage.

Direct and Alternating Current.—Direct current flows steadily in one direction, as from a storage battery, or a direct current generator.

Alternating current pulsates or flows first in one way then the other. A sixty cycle A. C. current reverses 120 times per second. The Ford magneto produces A. C. current, and at an engine speed of 1000 R. P. M. it reverses 1,600 times per minute or about 267 times per second. The producing of an A. C. current will be explained farther on in this work.

Magnetism.—Before one can understand the action of electricity they must be able to distinguish between electricity and magnetism. While they are two separate and distinct forms of energy, they are so very closely related that, if we have electricity we can produce magnetism, or if we have magnetism we can produce electricity. Magnetism is a form of energy which is possessed by the earth. There are two kinds of magnets, permanent and electro. A permanent magnet is one that retains its magnetism indefinitely due to the fact that it is made of hard steel. Soft iron can be magnetized very easily, but loses its magnetism very quickly. Therefore it cannot be used as a permanent magnet.

Electro Magnets.—When a current of electricity is sent through a wire there is a magnetic field built up about the wire, whether the wire is insulated or not, because magnetism cannot be insulated.

When a pebble is dropped in a pool of still water, rings will start at the point where the stone struck the water and

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will spread out until they come to the edge of the water. The magnetic field, or flux which is built up about the wire acts much in the same way except that it revolves around the wire in a clockwise direction when the current is flowing away from the observer, and in a counter-clockwise direction when the current is flowing towards the observer.

When more than one loop of wire is used and the insulation of the successive turns touch each other, and the turns are wound in layers, the flux does not surround each wire but around the whole coil as though it were one wire. If a soft iron core be placed through the loop of the coil, all of the magnetic influence is collected in the iron core and magnetizes it with a north pole at one end and a south pole at the other. If the coil is held up before the observer sideways so the current is flowing away from him in the wire that goes over the top of the core the left hand end will be a north pole. A magnet of this kind is an electro magnet and will only remain magnetized while the electric current is flowing.

Permanent Magnets.—By taking a piece of hardened steel and placing it across the poles of an electro magnet and allowing it to become charged with magnetism it will remain magnetized for an indefinite period of time depending upon the hardness of the steel. The reason for this is, steel is made up of millions of particles called molecules and in the natural state the molecules are each small magnets in themselves. Their poles are not lined up but all mixed up like grains of sand. When these molecules are brought near the influence of a strong electro magnet the poles are lined up,—all north poles pointing one way and all south poles the other way, making a north pole at one end of the bar and the south pole at the other. The strongest part of the pole is not at the extreme end but one-twelfth of the length of the bar from the end. Half way between the two poles is the neutral point of the magnet. It is because of this that the small end of Ford

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magnets which are in contact with the flywheel does not cause the magnets to be shorted.

Magnet Poles.—The relation of affinity of one magnet to another is a peculiar yet a very important thing. A magnet pole, either north or south, will attract a piece of iron or steel provided it is not magnetized. If it is magnetized only opposite poles attract each other,—a north pole will attract a south pole or vice versa. Two north poles or two south poles will repel each other. This is very important when assembling the magnets on the flywheel. They should be placed so they repel each other.

With electro magnets the influence or flux remains only while the electric current is flowing through the coil. With a permanent magnet the magnetic current if flowing all the time, as long as the magnet remains a magnet. This flow of flux is always in the same direction in regard to the pole (either permanent or electro) i. e., from north to south in the field and from south to north through the magnet itself.

In producing an electro magnet if the current is sent through the coil the core will be magnetized with a certain polarity. If the current is reversed through the coil the polarity of the core will be changed, also if a coil is passed through a magnetic field one way it will cause a current to flow through the coil in a certain direction, but if the coil is moved through the field in the opposite direction the current will flow the other way through the coil. This is what causes the Ford magneto to produce alternating current.

Relation of Electricity to Magnetism.—By sending a current of electricity through a coil wound around an iron core we produce a magnet. By moving a coil of wire through a magnetic field we produce electricity. If we have one we can produce the other. We learned before that silver and copper were the best electrical conductors but these metals will not conduct magnetism, in fact iron and steel are the only two common magnetic conductors. This is why the screws and spools under the ends

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of the magnets on the Ford car are made of brass and aluminum. Also we learned that by covering an electrical conductor with cloth or rubber or varnish the electricity could be confined to the wire or in other words the wire is insulated electricity, but there is no material or substance known to us at this time that will insulate magnetism, and it is because of this that an electrical current can be induced into an insulated wire.

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CHAPTER XI

THE IGNITION SYSTEM

Parts of the High Tension Jump Spark System.—The Ford ignition system is known as the High Tension jump spark system. It includes the following parts:

Induction Coil.—Or coil units to transform the primary (magneto) current of 8 to 24 volts into a secondary current of 8,000 to 20,000 volts. This is necessary as a current must be

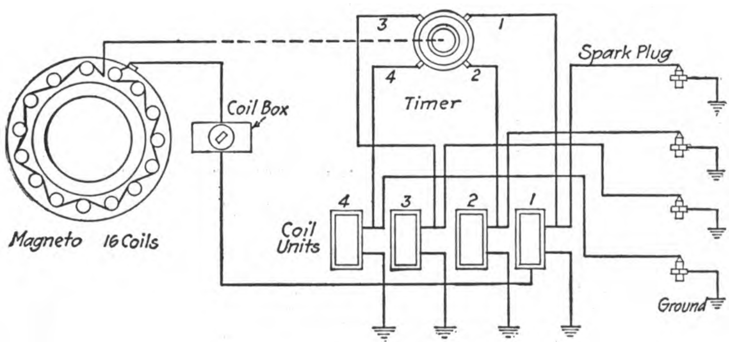

Fig. 29.—The Ignition System

provided which can jump an air gap of at least one-quarter inch.

Commutator.—Or timer, to close primary circuit and produce a spark in the cylinder at the proper time to fire the charge and start the power stroke. To control passage of current through different coils according to the firing order. To advance and retard the spark.

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Switch.—To start or stop current. When switch is "on" or "closed" current flows and the engine may be started. When switch is "off" or "open" current stops, and engine stops.

Spark Plug.—To conduct high tension current into the combustion chamber and provide a gap across which it must jump so as to set fire to the explosive mixture.

Wiring.—To conduct current from one part to another.

Magneto.—Flywheel type, rotating magnets, stationary field, alternating low tension current.

This magneto is of the inductor type, but unlike the other inductor type magnetos, the magnets themselves serve as inductors. It is designed to be mounted on the flywheel, thereby becoming a part of the power plant. It is protected from mechanical injury and moisture which tends to short circuit and damage it, by the same case which houses the transmission. The coils are stationary to avoid trouble from commutation or moving contacts.

The magneto is composed of sixteen "V" shaped permanent magnets. mounted on, but magnetically insulated from, the flywheel, and sixteen coils wound of insulated copper tape, one quarter of an inch wide and .015 in. thick, twenty-five turns to a coil mounted on bosses on the magneto frame. The coils are wrapped with cambric with a fiber insert in the center and bristol board insulating washers beneath when mounted on the bosses. The coils are connected with the winding of consecutive coils in opposite directions. After mounting the coils and connecting the terminals, one being on the fiber contact block the other grounded to the frame, the coils are impregnated with insulating varnish. They are given three coats and thoroughly baked to insure perfect insulation from moisture, oil and electrical leak. The coils are then tested to show the existence of any short circuits or grounds.

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The Magnets.—Are mounted with like poles of adjacent magnets together, making sixteen magnetic poles each having twice the strength of a single magnetic pole, so in each revolution of the flywheel the magnetism in the boss of each coil reverses sixteen

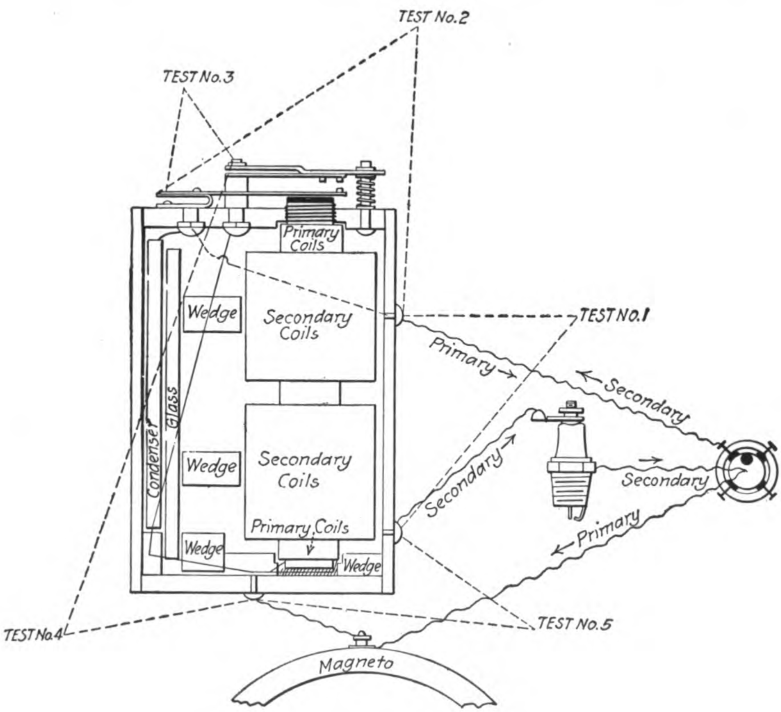

Fig. 30.—The Coil Unit

times, producing sixteen electrical impulses, which at ordinary engine speed produces a continuous alternating current of a much higher frequency than is used for house lighting. Because of this fact it is possible to operate lights from this magneto.

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The Coil Units.—The coil units consist of a soft iron core, primary coil, secondary coil, condenser and the upper and lower bridge. The coil unit is also called an induction coil. INDUCTION is the process by which a current is produced in one wire from a current flowing through another wire, near the first, but not touching it.

Construction.—The soft iron core is made up of 160 to 170 pieces of No. 20 Swedish soft iron wire and well insulated from the primary coil, which is wound around it by a heavy paper tube in which the core is packed.

The Primary Coil.—Is made up of two layers of No. 19 copper insulated wire. The first layer having 112 turns and the second 110 turns. The primary coil is then impregnated in hot paraffin and rosin for twenty minutes. This cements the pieces of wire in the core together, insulates and holds the windings of the primary in place.

The Secondary Coil.—Is composed of 16,400 turns of No. 38 enameled copper wire, and between each of the eighty-two layers are three layers of paper insulation. The coil is wrapped in two spools with forty-one layers on each spool. The reason for building the coil in two spools is because there will not be as many volts difference between the consecutive layers at the same end of the coil as though it were wound in one spool. By wrappng in two spools the difference in voltage between the consecutive layers at the same end is just half as much as it would be if wound in one spool, and consequently the thickness of the insulation between the layers is reduced one-half and the diameter of the coil is reduced proportionately. The secondary coil is then placed in a vacuum tank for twenty minutes at 220 deg. F. to make sure all moisture is drawn out, and then submerged in hot wax. A heavy piece of wax paper is wrapped around the primary coil and it is placed within the secondary coil making the induction coil complete.

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The Condenser.—Is composed of two pieces of tin foil seven feet long and three and one-half inches wide. One piece of this tin foil is placed on the other one but one-eighth of an inch to one side, with two layers of glassine paper insulation between and one layer on top and one layer on the bottom. It is then rolled up into a roll and placed into a vacuum tank for twenty minutes at 220 deg. F. and then boiled in paraffin for twenty minutes after which it is taken out and pressed and to each end terminals are attached. The condenser must test from 3 to 4 microfared.

The Condenser Terminals.—Have no electrical connection within the condenser. These terminals are connected in the primary circuit with one terminal on each side of the contact points. The condenser is used to absorb the self induced or reactionary current of primary windings at the breaking of the contact points and thus prevent it from opposing the rapid fall of the primary current. The more rapid the fall of the primary current the greater the force of the induced current into the secondary winding. The current absorbed by the condenser is forced out as soon as the primary circuit is opened at the points. Thus it helps to demagnetize the core more quickly.

The Upper Bridge.—Is made of brass and to this, at the terminal post, is riveted a cushion spring which is made of bronze. The other end of the cushion spring contains a tungsten steel point and this end is held from .003 to .005 in. from the upper bridge by a spacer rivet.

The Lower Bridge.—Is a copper spring by means of which the amperage can be adjusted by increasing or decreasing the tension on the armature which is attached to the lower bridge by two screws. The armature is made of Swedish steel and has a tungsten steel point on the free end, directly under, and in line with the tungsten steel point on the cushion spring. The parts are placed in the coil box, with the exception of the upper and

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lower bridge which is placed on top in their relative positions, and tar from 300 to 350 deg. F. is poured around them holding them in place, insulating them from each other and protecing them from dampness. The space between the points is adjusted from .029 to .031 in. The coils are adjusted from 1.2 to 1.4 amperes.

Path of Primary Current.—The current flows into the coil unit from the magneto or battery through the bottom contact, through the inner layer of the primary, then back through the outer layer of the primary, through a wire to the lower end of the condenser where it meets a wire leading it to the terminal post supporting the upper bridge, from there through the cushion spring, through the points, back through the armature, through the lower bridge terminal post to the upper end of condenser, to the upper side contact on the coil box, from there to a commutator segment, through the roller which is grounded, through the ground to the magneto or battery. This completes the primary circuit which magnetizes the core. The core attracts the armature and breaks the primary circuit by separating the contact points. At this moment the core is demagnetized and the armature returns to its normal position, again completing the primary circuit and the operation described above is repeated.

Path of Secondary Current.—The secondary current flows from the coil to the lower side contact on the coil box, from there through a high tension cable to the spark plug, jumps the air gap in the spark plug, and grounds to the engine; through the metal of the engine to the commutator roller and back through the primary wire to the upper side contact on the coil box, and from there to the other end of the secondary coil, completing the secondary circuit. There is no electrical connection between the primary and secondary circuit. The current is induced into the secondary coil by the increase and decrease of the

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lines of magnetic force around the primary coil caused by the making and the breaking of the primary circuit at the contact points. When the points are closed a current is induced in the secondary coil but it does not attain strength enough to jump the spark plug gap until the points break. This gives the induced current an added impetus which then jumps the gap in the spark plug and completes the circuit.

The Commutator.—Effects the make and break of the primary circuit. It determines the moment the spark plug must fire. The parts of the commutator or timer are roller brush or center, segments, terminals, shaft and cover. The roller is attached to the end of the camshaft and revolves with it at half the speed of the crankshaft. The brush or roller makes contact with the segments of which there are four in the commutator cover. When roller comes in contact with one of the segments the coil unit connected with it becomes operative. After the roller passes over the segment the coil unit is inoperative. The commutator cover is connected with the spark lever on steering wheel by a pull rod connection. By this lever the spark is advanced or retarded. By advancing the spark the charge in the cylinder is ignited earlier, that is, at the end or slightly before the end of the compression stroke. This gives the piston the full force of the explosion on the power stroke. By retarding the spark the charge is ignited later, or after the piston has started down on the power stroke.

Care of Timer.—Keep wires firmly secured. Once a month remove cover, wipe out inside, particularly contacts, with gasoline and cotton waste, oil frequently with a light oil. See that no grooves are worn in fibre. See that spring is in good condition, as well as fibre washer on the terminals.

Spark Plug.—The spark plug provides a means for igniting the gas in the combustion chamber. Champion X are the plugs used on Ford cars. The thread on this plug is half-inch pipe.

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Parts of Spark Plug.—Center wire or electrode, core or porcelain, shell and side wire, lock nut and gasket.

Care of Spark Plug.—Remove lock nut and take out core, being careful not to injure it or the gasket. Clean off carbon with gasoline or wire brush or cotton waste. Replace parts carefully, screwing down lock nut firmly.

Trouble Hunting.—If Engine does not Start.—See if:

Magneto contact is free of foreign matter.
All wires are connected.
All contacts are clean and tight.
Insulation on wires is worn.
Switch is turned on.
Vibrators are properly adjusted.
Timer wires are properly connected.
Roller revolves, is set right, spring is strong, fibre washer O. K.
Spark occurs at plugs.
Spark plugs need cleaning.
There is gasoline in tank and carburetor.
Carburetor primes properly.

Engine Misfires.—Causes.—

Dirty magneto contact point.
Loose wires.
Vibrator points pitted or dirty.
Vibrator points need adjusting.
Dirty timer segments (contacts).
Timer wires short circuited.
Dirty spark plugs, gap too small or too large.
Leaky spark plug core (broken porcelain).
Loss of compression in one or more cylinders.
Condenser open.
Weak mixture from carburetor.
Water in gasoline.

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Engine Misses at High Speed.—

Bad spark plug.

Sticking valve.

Loose electrical connection.

Weak valve spring.

Spark plug gaps are not set correctly.

Commutator case rough, causes roller to jump.

Engine Misses at Low Speed.—

Weak exhaust valve spring.

Bad spark plug.

Exhaust valves need grinding.

Leak in intake pipe or connection.

Engine Lacks Power.—

Late spark.

Poorly fitting piston rings.

Valves sticking.

Leak in intake pipe or connection.

Engine full of carbon.

Clogged gasoline line.

To Locate Cylinder.—Which is misfiring, short circuit spark plugs with screw driver. If it changes the running of the engine or sound of the exhaust it is a live cylinder, if it makes no change it is a dead cylinder.

To locate a cylinder that is misfiring on a vibrator system, hold down all vibrators, but one and see if remaining cylinder is firing. Hold down one vibrator at a time and see if it changes the running of the engine or sound of exhaust. If it makes no change it is a dead cylinder.

Conditions Necessary for Engine to Start and Run.—

Proper ignition.

Proper carburetion.

Sufficient lubrication.

Good compression.

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An efficient cooling system.

Given the five conditions above, the engine must run.

Always Retard Spark Before Cranking Engine.—Particularly with the battery system. If this is not done engine will start backwards and the operator may injure himself. When cranking with the self-starter retard the spark lever on steering wheel.

Spark too far Advanced.—Has the following effects:

When starting the engine, the engine kicks backwards.

When the engine is idling, engine races and consumes too much fuel.

Engine under load causes knocking which may be made severe enough to stop engine. Knocking hammers out the bearings and may cause them to come loose, resulting in serious injury to the engine.

Changing the Position of the Spark.—This can be done by moving the commutator case to the right or to the left so that the spark occurs before or after the piston reaches top dead center on the compression stroke. The reason for changing the position of the spark is on account of the variable speed of the automobile engine, where the piston speed is constantly being changed. When the pistons are moving slowly the spark must occur late, so that the gas will not expand before the piston reaches the top of the compression stroke, but after the pistons are starting down on the power stroke. If the pistons were traveling fast and the spark was retarded, the engine would lose power because the pistons would be quite a ways down on the power stroke before the expansion of the gas would take place. Therefore when the pistons are traveling fast advance the spark so that the spark ignites the gas before the pistons reach top dead center of the compression stroke, and by that time the gases are just starting to explode and the pistons are driven down on the power stroke with the force of the expanding gas

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on them for the whole length of the stroke. If the spark were advanced with the pistons working slowly, the expansion of the gas would take place before the pistons would reach the top of the compression stroke, having a tendency to retard the speed of the piston, drive the piston in the opposite direction and cause a severe strain on the crankshaft and the bearings and most important of all losing considerable power.

Coil Troubles and Tests for Locating Them.—In trying a coil on the test stand:

1. If the points vibrate with a heavy blue arc at the points and no spark on the test ring, the condenser is open.

2. If the vibrator at the points is noisy with no spark on the rest ring nor any are at the points and the ammeter hand flies across the dial, you have a short circuit condenser.

3. If the points vibrate properly with a weak or irregular spark at the test ring with the ammeter registering, the secondary coil is short circuited.

4. If the points vibrate properly and no spark at the test ring, the secondary circuit is open.

5. If there is no vibration at the points and the ammeter hand flies across the dial, then the primary is shorted.

6. If there is no vibration at the points and the ammeter hand does not register, then either the points are at fault or the coil is dead. File and adjust the points and if the ammeter hand still does not register or the coil still refuses to vibrate, then the coil is dead, and in order to find the exact location of the trouble, the test line should be used on the following tests.

1. By taking the test points of a 110 volt circuit and placing one point on one of the side terminals and striking the other point across the other side terminal there should be a spark produced but no light. If the light burns the secondary coil is shorted.

2. By placing one test point on the upper side terminal and one on the bottom terminal, this tests for the primary and the

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test light should burn. If it does not, it is an indication of an open circuit in the primary, and the trouble may be that the points are insulated. To determine just where the trouble is, first, file the points to be sure they are clean and making good contact; then test from the bottom contact to the upper bridge. If the light does not burn the primary wire in the coil box is

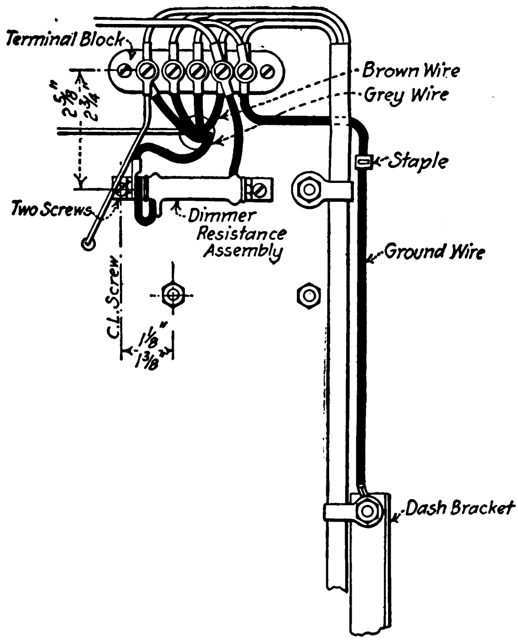

Fig. 31—The Dimmer Assembly

broken, but if the light does burn touch tests points to upper and lower bridge. If the light still does not burn the trouble is in the points. If it does, place one point on the lower bridge and the other point on the upper side terminal. You should get a light. If not, the wire leading between these two points is broken.

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3. To test the condenser, break the circuit at the vibrator points by placing a piece of paper or wood between them to insulate them. By placing the test points on the upper and lower bridges the condenser will be charged. Remove one point and short cross between the bridges, and a spark should be seen. This test, however, requires a direct current of more than forty volts. If no spark is seen the condenser is open, if the light burns the condenser is shorted.

Questions and Answers on The Ignition System

The Magneto

Q. What is a Magneto?

A. A magneto is a device for generating the electrical current necessary for ignition of the gas in the cylinders of the engine and for lighting the car.

Q. What are the advantages of using a magneto instead of a battery?

A. A magneto is a more reliable and more efficient source of electricity than the battery. It requires no attention and will not run down as a battery will. It always supplies sufficient current for starting when the car is cranked and for running after the car is started.

Q. What type is the Ford magneto and what kind of current does it generate?

A. The Ford magneto is the flywheel type. It is an alternating current generating with a stationary armature and revolving field of permanent magnets. It delivers low tension current, alternating sixteen times per revolution.

Q. Are there any moving contact points in this generator?

A. No. One feature of the Ford magneto which makes it so reliable is that no brushes or moving contacts are used in leading the current to the magneto terminal. The use of a revolving permanent magnet field and alternating current make the use of brushes or commutator unnecessary.

Q. What are the principal parts of a Ford Magneto?

A. The Ford magneto consists of a stationary coil with sixteen spools upon it each wound with copper wire or tape and connected together by that wire. The sixteen permanent magnets on the flywheel of the motor revolve past these spools generating an electrical current in the winding which is carried to the magneto connection.

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Q. What are permanent magnets? How are they made? How are they charged?

A. Permanent magnets are bars of hardened steel permanently magnetized. There is a relationship between electricity and magnetism, such that under certain conditions one can create the other. Magnets are usually made in horseshoe shape to bring the ends or poles of the magnet close together. This tends to make the magnetic force greater, and to conserve the strength of the magnet. Magnets are charged by being placed on electro-magnets.

Q. Why does a permanent magnet retain its magnetism?

A. A permanent magnet retains its magnetism because it is made of a kind of steel whose composition and hardness forces the molecules to remain in the position into which they were placed by the process of magnetizing.

Q. How many magnets on a Ford magneto and how are they placed in relation to each other in the flywheel?

A. There are sixteen magnets on the Ford magneto placed so the like magnetic poles are in contact. In this position none of the magnets will attract each other, or stick together. This increases the size of each magnetic pole and the strength of the magnetic field.

Q. How many coils are there on a Ford magneto and why? How are the coils connected?

A. There are sixteen coils on a Ford magneto, one for each magnetic pole on the flywheel. Each coil is placed on its spool and connected in such a way that the current flows through it in an opposite direction to that of the coils on each side of it. The coils are all connected in series. The coils are grounded at one end and connected to a contact point on the other which in turn connects to the magneto terminal on the transmission cover.

Q. How many turns of wire are there on each coil? What size is it? Why is flat wire used on a Ford magneto?

A. There are twenty-five turns of wire on each coil and sixteen coils, giving 400 on the entire coil disc. The wire is .025 x .025. Flat wire is used to concentrate the number of turns into the smallest possible space.

Q. What is high tension current? Low tension current? Voltage? Amperage? Direct current? Alternating current?

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A. Voltage is the force of the electrical current in overcoming resistance. It corresponds to the pressure of a stream of water. Amperage is the quantity of electricity in the current. It corresponds to the volume of flow in a stream of water. High tension means a current of great voltage or force. Low tension is one of small voltage. A direct current is an electric current flowing constantly in one direction. An alternating current is an electric current flowing in opposite directions in rapid succession.

Q. How can you tell if a magneto is weak?

A. If the motor is hard to start by magneto and starts easily by battery, the magneto is probably weak. If an alternating current volt-meter is connected to the magneto terminal and ground and shows less than 8 volts reading with engine throttled down, the magneto is weak.

Q. What would cause a weak magneto?

A. A weak magneto is caused by:

Weak magnets on the flywheel.
Magnets out of regular order on the flywheel.
Broken transmission tie wire, or metal causing short circuit.
Dirt or foreign matter under the contact post.

Q. What would cause the magnets of the magneto to lose their strength?

A. The magnets on the magneto will lose their strength if a storage battery is used and battery is connected to the dash terminal of the magneto. Even when a storage battery is used on the proper terminal the magnets may become weakened if defective wiring causes a leak of the current back through the coils.

Q. Does a magneto build up in strength or become weaker in use?

A. A magneto never builds up in strength and the chances are that the magnets will weaken after several years.

Q. How can you tell if a magneto is dead?

A. If a magneto is dead no spark will be secured, so if the car runs all right on a battery and engine stops when switch is thrown to magneto the magneto is dead.

Q. How do we test a Ford magneto for a short circuit? How do we test for a ground?

A. In testing for a short circuit, an electric current of certain known strength is run through the coils and the metal dial regis-

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tering will show whether any portion of it has escaped through leakage or short circuiting. When a magneto is grounded, all coils below the ground are cut out of the field leaving only those between the ground and the contact post for carrying the current. This condition is tested by meter test or test light, making contact at different points to ascertain where the grounding exists by seeing just how far around the coils the current will go effectively. This test of course cannot be made without taking the magneto out of the engine.

Q. Why do we insulate the coils of a Ford magneto in varnish?

A. Varnish insulation is used on the coils to protect them from leakage of current or short circuiting. The varnish increases the strength of the insulation on the coils.

Q. Why are only the connections between the first five coils connecting with the contact point insulated?

A. Wherever there is a short circuit between a coil and the coil disc all the coils between this point and the grounded coil are cut out. To prevent a short circuit from cutting out enough coils to disable the magneto the connections between the first five coils are insulated.

Q. What effect does dirty oil have on a magneto?

A. Dirty oil may carry foreign matter to the contact post and obstruct the flow of the current. Old, dirty oil is burned oil, and contains more or less of the carbon particles which accumulate and tend to cause the magneto to leak or short circuit. Minute metal particles in oil may have the same effect.

Q. What effect would a piece of metal have if it became lodged between magneto coil and magneto support?

A. A piece of metal lodged between magneto coil and magneto support would cause a short circuit. It would cut out the coils below it, leaving only those between it and the contact post for effectively carrying the current which would not be sufficient to give the desired strength.

Q. What are some of the causes of a short circuit on magneto?

A. The magneto will be short circuited if:

The coil is broken and comes into contact with any metallic part.

A piece of metal becomes lodged in the magneto in such a position that it can carry the current.

A broken transmission tie wire makes connection in such a way

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that it carries current. Graphite or metallic particles in oil accumulate and form a connection which would carry current.

Q. What effect would a piece of brake band lining have if it got between magneto contact and contact point?

A. Any foreign substance such as a piece of brake band lining under the contact point of magneto would prevent proper contact and obstruct the flow of the current.

The Commutator

Q. What is the purpose of the commutator?

A. The commutator determines the instant at which the spark jumps and the cylinder in which it jumps. In short, it regulates the time and order of firing.

Q. How does the commutator determine the order of firing?

A. The primary circuit of the four coil units are connected to the four contact segments in the commutator. When the commutator roller comes into contact with one of the segments it completes the primary circuit of the coil connected with this segment causing a spark to jump at the spark plug connected to the secondary of this coil. Thus the connections to the commutator segments determine the order of firing.

Q. Explain how the commutator regulates the time of firing.

A. The commutator cover in which the contact points are imbedded can be turned to the right or to the left by the spark lever on the steering wheel. When it is turned against the rotation of the roller, the roller comes into contact with the segments sooner than before. This advances the time of firing. When moved in the other direction it retards the time of firing.

Q. How is the commutator brush put on? Why in that position?

A. With front valve door removed and #1 exhaust valve open (push rod up) commutator brush should point down. With #2 intake valve open (push rod up) commutator brush should point up. Commutator brush must be set in this position so it will pass over the metal contact points inside commutator at the right instant to explode the compressed gas when piston is at top of its stroke in the proper cylinder.

Q. What care should be taken of commutator?

A. See that the commutator is oiled almost daily, for every 200 miles drive at least, and remove the cover for cleaning it out thoroughly occasionally. Sticky or gummy oil deposits prevent proper contact and cause difficulty in starting engine.

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Q. Why is the wire on #3 segment of commutator connected to #4 coil terminal?

A. #3 wire on commutator is fastened to #4 terminal on coil so that motor will fire in the proper order—#1, #2, #4, #3.

Q. What precaution should be taken regarding the commutator in cold weather?

A. In cold weather oil thickens or congeals on the commutator roller and contact segments. This prevents the roller from making a good contact with the segment causing misfiring. To overcome this, as well as any liability of the contact to rust, it is recommended that a mixture of 25% kerosene be used with the commutator oil.

Q. What effect will be caused by irregularity in the contact segment of commutator or badly worn segments?

A. If the contact segments are irregular the jumping of the commutator roller may be causing misfiring. If the segments are badly worn, imperfect contact with the roller may cause irregularity in the firing of the cylinders and so irregularity and lack of power in the motor, or excessive vibration in the engine.

Q. What will happen if the commutator terminal connection on the cover becomes grounded?

A. If a commutator is grounded through a terminal connection on the commutator cover, that particular cylinder in the engine will fire constantly and it will be impossible to start the engine without a dangerous back-kick. Such grounding may occur from the commutator wire touching the cover or from an oil or water soaked washer under cover contact post acting as a conductor for the current.

Q. How is the circuit completed between the magneto and the commutator roller?

A. The primary circuit is completed by the flow through the metal parts of the engine. The commutator roller is connected to the camshaft. The magneto coil wire is fastened or grounded at one end to the coil casting. This allows the current to complete the circuit between the ground wire in the magneto and the metal roller in the commutator, the cylinder case and metal parts connected to it.

Q. If a commutator wire comes into actual contact with any part of the car, what happens?

A. If a commutator wire has the insulation broken or worn so the

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wire comes in contact with any metal part of the car, a short circuit occurs which will cause premature explosion of gas. The engine will pound and lag because of the premature explosions. One of the coil units will usually buzz steadily when this condition exists. Care must be taken in starting an engine in this condition as the short causing the premature explosion is apt to result in a vigorous kick-back.

SPARK COIL UNITS

Q. What is the function of the Ford spark coils? Why are there four spark coil units in the Ford car?

A. The spark coil is an electrical instrument used to transform the low tension current of the flywheel magneto to current of high enough voltage to cause a spark to jump at the spark plug gap. One coil is used for each cylinder to avoid the use of a distributor, necessary where a single coil is used.

Q. Of what does a spark coil consist?

A. Each spark coil consists of a primary coil winding, a secondary winding and a condensor; also a soft iron core for the primary coil and vibrator arm.

Q. Describe the primary coil. Describe the secondary coil.

A. The primary coil is a coil of 220 turns of comparatively coarse wire, #19 B & S gauge, wound around a soft iron core. The primary current from the magneto passes through this winding. The secondary coil is a coil of 16,400 turns (about a mile in total length) of very fine wire #39 B & S gauge. The secondary current is induced in this winding from the primary coil winding.

Q. How is the Ford primary electrical current produced? Trace the primary current.

A. A magnet passing close to a coil of wire causes an electric current to flow through the coil of wire. The 16 magnets on the Ford flywheel revolve close to the 16 coils of wire on the stationary coil unit and create an alternating low tension current in those wires. The primary current is carried from these coils to the magneto contact post and from there by a wire connection to the coil box in the dash and passes through the primary coil of the spark coil unit. Wires from the coil box connections on the dash carry the current to the commutator and the circuit is completed back through the frame of the motor to magneto, whenever the commutator brush is in contact with the metal contact points in the commutator.

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Q. Why is the primary coil core made of small wires instead of one piece of soft iron? Why is soft iron used?

A. The core of the primary coil is made of small wires instead of one piece of soft iron to eliminate the overheating of the core and also because the small wires demagnetize more readily than a solid core. Swedish wrought iron—very pure soft iron is used because it will not retain its magnetism, but gives off readily and quickly.

Q. What will happen if primary coil is short circuited?

A. If the primary coil is short circuited the coil box absolutely will not work at all.

Q. Why are primary and secondary coils so heavily insulated from each other?

A. The difference in voltage between the primary and secondary coils is so great that extra insulation is required between them to prevent the current forcing its way across. The voltage in the primary coils is from six to thirty-four volts; that in the secondary coils is from 8,000 to 20,000 volts so it requires heavy insulation.

Q. Why is the secondary coil wound with a great number of turns of small wire?

A. The secondary coil is made of a great number of turns of small wire because it is one of the laws of electricity that the finer the wire and the greater number of turns in the coil, the higher the intensity or voltage of the current. A high voltage is required to produce the strong spark necessary to fire the gas charge under compression. As an illustration, the coarse primary winding might be compared to a hose with a nozzle off. A large quantity (amperage) flows through it at low force (voltage) but when a nozzle with a small opening (fine wire) is used for an outlet, the force (voltage) of the stream becomes great though the quantity (amperage) is less. Force is required to throw the stream through any great space, or to make the current jump the spark plug gap, so the small nozzle (fine wire) is necessary.

Q. Why is the secondary coil so heavily insulated?

A. If all the layers of wire are short, the potential difference between them is small which makes it easy to insulate them from each other.

Q. Why is the secondary coil so heavily insulated?

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A. The secondary coil must be strongly insulated because the voltage of the current is so strong that it will force its way across any ordinary resistance.

Q. How is the secondary electrical current induced?

A. The secondary current is a high tension current, produced by induction in the secondary winding of the coils in the coil box by the primary current. There is no connection whatever necessary between the primary and secondary coils. The currents are absolutely separate and distinct, the secondary current being produced by the law of electricity known as induction. The secondary coil winding is hollow and slips over the primary winding with insulation between. The primary current through the primary winding induces the secondary current in the secondary coil surrounding the primary.

Q. About what voltage is delivered by the secondary coil?

A. The voltage delivered by the secondary coil varies with the speed of the motor and the strength of the magneto, from 8,000 to 20,000 volts. The proof of this is that 10,000 volts will cause a jump spark ½-in. long. The spark from the secondary coil varies from slightly less than ½-in. to 1 in. long, at different speeds, proving that the actual voltage is 8,000 to 20,000. The amperage is so small that this voltage can pass through the body without injury.

Q. Trace the course of the secondary current.

A. The high tension current induced in the secondary winding of the coils by the primary current is led from the secondary coil to the spark plugs, across the air gap through the motor to the commutator roller, then to the segment in contact with the roller and through the commutator wire into the primary coil where it is connected to the secondary. At this point it flows back into the secondary completing the circuit.

Q. Why is the secondary coil grounded to the primary coil on the inside of the box?

A. The secondary coil is grounded to the primary coil on the inside of the box to provide for an outlet for the secondary current, or to complete its circuit while firing the gasoline charge. It is grounded inside the coil box simply to save the extra wire which would be required for an outside grounding.

Q. What is the purpose of the condenser and of what does it consist?

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A. When a primary circuit is broken a momentary surge of current of high enough voltage to cause a spark to jump at the break is induced. With the condenser across the break it absorbs this current, eliminating to a great extent the spark and at the same time receiving a charge. When the vibrator points which makes the break come together again, the condenser discharges through the primary helping to build up the magnetism of the core. In short the condenser has two purposes; First, to eliminate the spark from the vibrator points thus preventing their burning up. Second, it absorbs the primary induced current (which would otherwise be wasted) and gives it up to add to the strength of the core. The condenser consists of two sheets of tin foil insulated from each other by a dielectric or insulating paper. Two sheets of paper separate the tin foil and each side is covered with a single sheet. This is rolled up to make the condenser compact.

Q. Where is the condenser connected to spark coil?

A. The condenser is connected in the primary circuit of the coil box across the points of the vibrator. When the vibrator points are closed the condenser is cut off or shunted out of the primary circuit. At the instant of discharge when the contact points come together the voltage in the condenser is added to the voltage in the secondary.

Q. Why is plate put between condenser and coil?

A. To insure insulation between them.

Q. With 200 turns on the primary and only 16.400 on the secondary, how do you account for a secondary voltage of 8,000 to 20,000 volts from a magneto current of about 14 volts.

A. The ratio of turns is about one to eighty so that a primary voltage of about 14 volts should produce about 112 volts in the secondary winding by induction. The addition of the voltage stored up by the condenser, together with other factors, increases this voltage to 8,000 or more, as proved by the length of spark.

Q. What effect would a short circuited condenser have upon the spark coil?

A. A short circuited condenser will give no spark at the spark plug. The vibrator goes down and sticks there. The coil unit will not work at all.

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Q. What effect would an open circuit condenser have on the spark coil?

A. An open circuit condenser will give no spark at the spark plug and cause excessive sparking at the vibrator points.

Q. What effect would a weak condenser have on the spark coil?

A. A weak condenser will cause a weak spark in the spark plug because an insufficient condenser voltage is added to the induction voltage.

Q. Why do we use a vibrator on a Ford coil?

A. The vibrator is a sort of a safety valve which allows just the desired amount of current through the coil. This amount is regulated by adjustment of the vibrator spring tension. The vibrator is placed on the primary circuit to make and break the circuit when the desired amount of current passes through the primary. The use of the vibrator also permits using few turns of wire on the secondray winding, to secure the desired voltage, because of the action of the lines of force across the gap.

Q. What is the armature and what is it made of?

A. The armature is the vibrating member of the vibrator. It is made of spring steel.

Q. What are the vibrator points made of?

A. Tungsten steel.

Q. What should the width of the gap be between the vibrator points?

A. .029 in.

Q. What is the purpose of the cushion spring?

A. The cushion spring lengthens the time of flow of current in the primary allowing the core to be more fully matured. It also allows the vibrator to work much smoother and with less wear.

Q. What should the gap be between the upper bridge and cushion spring?

A. .005 in.

Q. What causes the vibrations of the vibrator?

A. The vibrator is simply a strip of thin metal held by a spring from actual contact with the soft iron core of the primary winding. When sufficient current passes through the primary, the magnetizing of the core overcomes the tension of the spring and draws the vibrator down which opens the circuit. Then due to the fact that the core is of soft iron it demagnetizes

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very quickly and the tension of the springs draws the vibrator up closing the circuit again.

Q. How many vibrations occur while commutator roller is passing over each contact segment?

A. The vibrator makes four vibrations for each contact segment to the commutator. There are sixteen coils on the coil disc, four to each quarter turn. The vibrations occur at the "crest of the wave." The high points occur when the magnet poles are midway between the spools on the disc.

Q. How do you adjust the vibrators on the coil units?

A. The only proper way to adjust the vibrators on the Ford car is with a volt-meter and ammeter on a test stand, using a voltage of six to eight volts and adjusting the vibrators to draw 1.2 to 1.3 amperes. It is almost impossible to try to get the proper adjustment on the coil units by trying to adjust them in the car.

Q. Why should a coil box be tested on a test stand with a meter instead of in a car?

A. Testing on a test stand with meters, you get an accurate result. Adjustment which seems correct when the car is idle is not the same when the engine is working under the load of running the car. So the only uniform method is on the stand.

Q. What voltage and amperage should be used to set a coil?

A. In adjusting the vibrator spring, set the tension so that between six and eight volts with an amperage of 1.2 to 1.3 will draw down the vibrator. If the coils draw more current than this they would rapidly burn out the vibrator points. A battery usually delivers six volts. That is one reason the spring tension is adjusted to six volts. If adjusted for much more it would not work well on a battery. Adjustment for higher voltage than eight volts would make the car hard to start on the magneto, because there is only that amount of current produced when the engine is turned over by hand in cranking.

Q. Can the Ford coil units be used on direct current?

A. These coil units are universal coils. They can be used with a battery on direct current, or with the magneto on alternating current.

The Electric Spark

Q. Why does ignition occur in the combustion chamber before the end of the compression stroke?

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A. Ignition takes place before compression is completed because combustion is not instantaneous and by the time combustion is completed the piston has reached top center and is ready for impulse stroke.

Q. What effect has a retarded spark on the engine while running?

A. If the spark is retarded while running, the explosion occurs after the piston has begun its downward stroke, resulting in loss of power and loss of engine speed under ordinary driving conditions on good roads. The spark should only be retarded when the engine slows down on a heavy road or steep grade, but care must be used not to retard the spark too far, for when the spark is too late instead of getting a powerful explosion a slow burning of the gas with excessive heat will result.

Q. How can you tell when you have your spark in proper position while driving the car?

A. The spark lever should be in the position which results in the greatest engine speed for the amount of gasoline admitted by the throttle. It is usual to advance the spark as far as possible without the engine knocking. The best position for ordinary driving is usually about half way on this quadrant, though sometimes still further advancement gives better results. This all depends on the adjustment of the pull rod on commutator cover.

Q. Why on some spark plugs does the outside wire turn up instead of making contact at end of center pin?

A. The spark plug with the side wire turned up allows any oil to run below the point of spark. This tends to keep the spark points dry.

Q. What does unburned oil do to a spark plug?

A. Oil is a very good insulator and therefore prevents a spark from jumping the gap.

Q. What does a heavy carbon deposit do to a spark plug?

A. Carbon is a conductor of electricty and therefore the current flows through the carbon path diminishing or eliminating the spark at the gap.

Q. What defect besides carbon or oil will make a spark plug misfire?

A. A cracked porcelain will allow the spark to jump through the crack and not at the gap.

Q. What trouble besides ignition must be guarded against in spark plugs?

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A. It is important that a spark plug does not allow a loss of compression through gas leakage.

IGNITION TROUBLES

Q. If your engine is missing how would you find out whether it is caused by ignition trouble?

A. If one cylinder in the engine is missing fire, by holding down the vibrators on the coil units in succession, one may be found which seems to have no effect on the actual operation of the engine. The trouble is then ignition trouble and will be located in the unit, or the spark plug connected to that unit, or the wire connections to it, or in the commutator section corresponding to that unit.

Q. If your engine is missing how would you find out if it is coil trouble?

A. If all conditions seem correct and the engine is still missing or one cylinder is weak, change the position of the coil unit governing the faulty cylinder explosions. If the trouble follows the coil unit, the fault is in that unit.

Q. If a coil is giving trouble how can you tell if it is condenser trouble in the unit?

A. If the unit is working all right apparently, but you have excessive sparking at the vibrator points, you know you have condenser trouble.

Q. How can you tell when the primary coil of a coil unit is defective?

A. If the vibrator in the unit will not work at all with a proper gap existing the primary winding is short circuited or open. Your trouble is in the primary coil.

Q. How can you tell if the defect is in the secondary coil of the coil unit?

A. If the vibrator in the unit is working properly but you get no spark from the secondary winding (the spark plug) the secondary winding is defective.

Q. How can you tell if trouble is in the vibrator?

A. If the vibrator is sticking or has dirty contact points or the cylinder on that particular coil unit is misfiring at times, the trouble is in the vibrator itself.

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CHAPTER XII

THE FORD GENERATOR

The electrical equipment consists of a storage battery, starter, generator, combination switch, cut-out, ammeter, starting switch, lights and the necessary wiring.

Purpose.—The battery supplies current for the starter and

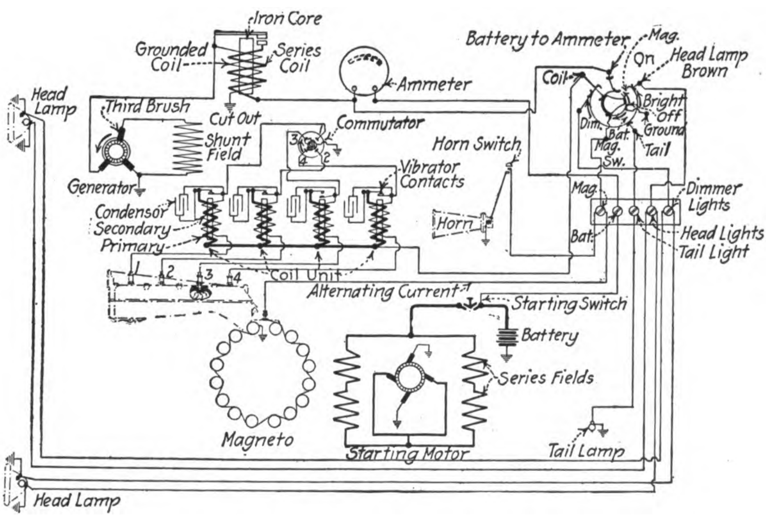

Fig. 32—The Ford Starting, Lighting and Ignition System

lights. It may be used also for ignition if desired. If there were not some means of recharging the battery it would soon become exhausted. Therefore, the purpose of the generator is to keep the battery charged.

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Location.—The generator is located on the right forward side of the engine and is supported by the time gear housing. The gear on the end of the generator armature shaft is in mesh with the large time gear. Therefore, the armature rotates in the opposite direction to the large time gear, and in the same direction as the crank gear.

The crank gear has 24 teeth; the generator gear has 16 teeth, making a ratio of 1 1-2 to 1. Therefore, when the crank is turning 1,000 R.P.M. the generator is turning 1,500 R.P.M.

Parts and Purpose.—*The Yoke,* or housing is to enclose the working parts, provide a connection or yoke for the field poles, and to conduct the magnetism from one pole to the other.

The Poles.—Or iron shoes of which there are four, placed at intervals of 90 deg. around the inner surface of the yoke, form the magnets which produce the field.

The Field Coils.—Are the coils wound around the field poles, the purpose of which is to magnetize the field. These coils receive their current from the third brush.

The Armature.—Consists of a laminated iron core, armature coils, and a commutator. The armature revolves inside the housing and is supported by a ball bearing at each end of the armature shaft.

The Armature Coils.—There are 21 coils of ten turns each wound on the armature core. These coils produce the charging current.

The Commutator.—The generator commutator is made up of 21 copper segments and when assembled forms a cylinder against which the brushes bear. The purpose of the commutator is to collect the current which is built up or produced in the armature coils, but, unlike a collector ring as used on magnetos or A. C. machines it has 21 sections or segments, each insulated from the other with mica except through the coils. Both ends of the armature coils are on the commutator end of the core, one end or lead is connected to a segment on the commutator. The

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other end of the coil is connected to a commutator segment which is the eleventh segment around the commutator from the one to which the first end of the coil is connected or almost diametrically opposite on the commutator. It may be seen that with 21 coils and 21 slots in the commutator each slot has one of two different coils in it.

The Brushes.—There are three carbon brushes in the generator; two large or main brushes and one small or third brush. One of the main brushes and the third brush are positive brushes. The other main brush is negative.

The Brush Holders.—Each brush is held in a metal socket called a brush holder. These holders are supported by a metal ring called a brush ring. One of the main brush holders, the positive and the third brush holder, are insulated from the brush ring. The other main brush holder, the negative, is grounded to the brush ring.

Brush Springs are used to press the brushes against the commutator.

Pigtails, or small flexible cable, form better electrical connections between the brush holder and the brush.

Placing of Armature Coils.—The coils are placed on the armature core in succession or one after the other all the way around. With the 21 coils all in place and connected up there is an electrical connection through the whole armature. It is for this reason that when the test wire is put on one segment of the commutator and the other point placed on the adjacent segment the test light will burn. This should not be taken for a short circuited commutator.

Explanation of Action.—Nearly everyone understands that the generator produces the current which lights the lamps and charges the battery, but, few understand how it is produced.

If you recall the three things which are necessary to produce an electric current, i. e. magnetic field, number of turns in

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the coils, speed and movement, they may be applied to the generator.

Unlike the magneto the generator magnets are electro magnets and are called poles. These produce the magnetic field. There are 21 coils of ten turns each on the armature. The armature being geared to the crankshaft gives the armature the speed and movement when the engine is running.

The question may arise, how can the generator start to generate if the poles lose their magnetism when the generator is stopped, as would be the case of the core of an electro magnet if there is no current passing through the coil wound around it?

While the core or poles lose the most of their magnetism when the generator stops they do not lose all of it. In other words, the poles retain a small amount of magnetism called "Residual" magnetism, or the magnetism that remains or resides in the core of an electro-magnet after the magnetic influence is stopped. However, the residual of magnetism is sometimes destroyed, in which case the generator will be dead or will not start to generate. This may be remedied by disconnecting the wire which leads from the ammeter to the cut-out at the cut-out terminal for a short period of time, 15 or 20 seconds; this allows the battery current to flow through the generator field coils, the current flowing through the coils causes the pole pieces to be magnetized and when the current is discontinued the pole pieces retain some of the magnetism. This may be done without removing the generator from the car. However, if the generator is removed the residual can be built up by motorizing the generator for about an hour, in fact when the generators are built up they are always motorized for that purpose.

Regulation.—The battery is charged by sending a current of electricity through it. In the first place this must be a direct current; therefore, the magneto cannot be used.

Second, it is very important that the output of the generator (or in other words the charging rate) be steady or constant,

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which is not true of the magneto or series wound machines, because of the variation of the engine speed. This is why it becomes necessary to have some kind of regulation to prevent the current at high speeds being too high.

The normal output of the Ford generator at ordinary speeds is about eight to ten amperes. At 1,500 R.P.M. of the generator it should be eleven amperes and should not run over twelve amperes at any speed.

On this system the charge rate is regulated by the third brush method.

If the generator were a series wound machine the output would depend upon the speed, because in that case the entire output of the machine would flow through the field coil to produce the magnetic field. With the Ford generator the current which flows through the field coils is only a part of the current which is produced by the generator. In fact there are two circuits, the charging circuit and the shunt field circuit. The charging circuit current is collected from the commutator by a large positive brush, and the shunt field circuit is collected from the commutator by the 3rd brush.

The strength of the field poles depends upon the amount of current which flows through the field coils. The output of the generator depends upon the strength of the field poles. The amount of current which will flow through the field coils depends upon where the 3rd brush is set on the commutator in relation to the negative or grounded brush. In order to *increase* the output of the generator the 3rd brush should be moved in the direction of the armature rotation. To *decrease* the output it should be moved in the opposite direction from which the armature rotates.

Trouble.—As long as the charging indicator begins to show charge at a car speed of eight to ten miles per hour, and builds up to ten or eleven amperes around twenty-five miles per hour (lights off) and does not exceed twelve amperes at higher speeds

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and the ammeter hand does not fluctuate or shake and the generator does not heat up, the indications are that the generator is operating in a satisfactory manner.

If the ammeter does not show charge when the engine is running, or, if the charge rate is low or high, and the generator heats up, or the ammeter shows discharge or the hand vibrates, there is something wrong.

If the ammeter does not show charge see that all connections are tight, (turn on the lights to see if the ammeter is operating by showing a discharge) next short across from the terminal on the top of the generator to the screw on the cut-out to which the cut-out to ammeter wire is attached, the possibility of the trouble being in the cut-out would be brought out. A current would then flow direct from the generator to the battery showing that the trouble was in the cut-out. If no current flow is shown at the ammeter see if the ammeter shows discharge, if not, this indicates an open circuit somewhere in the line. If this is the case, by shorting across from the generator terminal to the housing sparks would be produced. If no sparks appear the generator is dead. This may be due to the following causes:

1. Dirty commutator.
2. Sticking brushes.
3. Weak or broken brush springs.
4. Grounded or open field coils.
5. Shorted, open, or grounded armature.
6. Grounded positive or third brush holder.

Systematic Trouble Hunting.—(Short Methods).

1. In testing for the above troubles but before removing the generator from the car, clean commutator with fine sand cloth (00 or 000) (*never use emery*) also magnetize poles as instructed before, also adjust 3rd brush in direction of armature rotation. If these fail to remedy the troubles the generator will have to be removed from the car. (Laying generator on the motor block

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forms a ground connection). Before going ahead with No. 2 and No. 3 tests apply ammeter-cut-out wire to generator terminal and if the armature rotates in a counter clock-wise direction when looking at generator gear end and cannot be made rotate the right way by loosening the four screws on the head, and turning the brush ring in the direction which it should turn, the 3rd brush and grounded brush wires are reversed. This is very important because some of the field coil leads are crossed and some are not, and unless you know the proper way to assemble them they may be wrong. This is a positive test.

Repairs.—1. Dirty commutator, this has been previously mentioned.

2. If the brushes are sticking and not working free in the brush holder they should be removed and dressed with a fine file.

3. The spring tension should be sufficient to hold the brush firmly against the commutator, if the springs are weak or broken they should be replaced with new ones.

4. If the field coil is grounded it is likely to be where the wire leading from coil to coil will be in contact with the yoke or housing. This may be remedied by slipping a piece of insulating paper between connection and housing. Another cause may be where the pole pieces are drawn through the field coil breaking the insulation. This may be remedied by disassembling the coils from the yoke and covering the bare wires with tape. If not, reshellac field coils, let dry, and reassemble. Open field coils will also be in the connecting wire between the coils. Connect by hooking the wires together and *soldering* in order to get a good permanent connection.

5. An open armature is usually in the connections on the commutator, these may be reconnected and soldered. A shorted or grounded armature should be returned to the Company's branch for credit.

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6. If the positive or 3rd brush holder is grounded it may be caused by dirt or oil. This can be remedied by washing well with gasoline. If it does not overcome the ground the trouble will be in the 3rd brush holder being drawn too tight and breaking the insulation. In this case the brush ring will have to be replaced.

Reassemble.—When the generator is assembled great care should be taken in setting the neutral point, and the sanding of the brushes.

Neutral.—With the 3rd brush raised and the current from the battery applied to the generator terminal, the current passes through the armature coils but not the field coils; therefore, the armature core is magnetized having four poles. The neutral point is when the poles on the armature core are just half way between the pole pieces. The attraction will be equal in both directions. If the brushes are shifted in either direction the armature poles will be nearer to one side of the pole piece than the other, therefore, the armature will have more attraction in one direction, and will rotate in that direction. In order to set the neutral point in correct position it should be just slightly in the direction of armature rotation from dead "neutral" but not enough for it to rotate, and just have an inclination to revolve; or, in other words have more attraction in the direction of rotation than the other way. This is very important, because if not correctly set the generator will heat up. When the 3rd brush is dropped the armature will start to revolve in the direction of rotation as when attached to the car.

Sanding Brushes.—A very important part in the satisfactory operation of a generator is the manner in which the brushes make contact with the commutator. Each brush should have 100% bearing surface in width and not less than 75% in length. If they do not they should be sanded in. A tool for this purpose may be procured from the tool equipment companies.

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Discharge.—If the ammeter shows discharge it may be that the ammeter is reversed or the wires connected wrong. Always connect wire from cut-out to the charge side of the ammeter. If on replacing, the ammeter still shows discharge, the cause is probably wrongly connected battery, as this causes the generator poles to be reversed and the current to flow the opposite way. *Always* connect the negative side of the battery to the ground on this system.

The Generator Cut-out.—The cut-out on the generator is simply an automatic switch to close the charging circuit when the voltage of the generator overcomes or exceeds that of the battery. It also opens the circuit when the engine stops to prevent the battery from discharging through the generator.

There are two coils of wire wound on the cut-out core, the voltage or fine coil of 1,300 turns, and the series or heavy coil of ten turns.

Action.—The fine coil is the voltage coil and the voltage circuit is always closed. As soon as the engine starts to run the generator starts to build up and a small current starts to flow through the shunt field circuit. The current flowing through the 1,300 turns of the voltage coil magnetizes the core of the cut-out, pulls the points together and they remain closed as long as there is any current flowing to the battery, because the charging circuit flows through the series coil which is wound on the core in the same direction as the voltage coil. The two coils work together and magnetize the core to a greater strength. As soon as the current stops flowing the core loses its magnetism and the spring pulls the points apart.

The cut-out is tested for closing at seven and one-half volts or at about 700 R.P.M. of the generator and for closing at zero, or when there is no current flowing to the battery.

Detecting Defects in Cut-outs.—When a test stand is not available disconnect cut-out from generator and battery and con-

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nect a volt-meter from the positive terminal of the generator to the ground. Start motor and throttle to speed which will develop nine volts in generator on open circuit. Hold cut-out in position by hand and defects will show as follows:

Grounds.—Volt-meter will drop to zero showing no voltage. Remove cover and examine insulation, see that no part of the cut-out is in contact with base, also the series coil may be in contact with the cover. When this occurs press wire back to avoid covers.

Open Circuit Voltage Coil.—When voltage coil is open the volt-meter will remain constant at nine volts; when the voltage coil is O. K. the voltage will drop from nine to eight and one-half volts. To locate an open circuit in voltage coil examine terminals of inner coil at either the ground connection to base, or positive connection to pole piece, both of which are soldered thereto. The open circuit will be found at one end or the other. When found carefully resolder.

Open Circuit Series Coil.—This condition may exist from any of the following causes. The terminals of the series coil, one of which is soldered to the insulated point which is mounted on the cut-out, the other is soldered to the battery contact. Examine each contact carefully and when found to be loose, re-solder. The terminal mounting on the armature supports a silver point which is riveted to the cut-out armature, or keeper will not close on account of the armature striking the magnet core. This error can be corrected by bending terminal outward so that when the points are brought together the clearance between armature and magnet core, is approximately 1-32 inch air gap. This clearance will also compensate for wear at the points. Never allow the armature to touch the magnet core when points are closed as this condition will make the points stick on opening, due to residual magnetism. When the points are apparently together and no current flows, this indicates dirty

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points. Draw a piece of No. 00 sand paper through points reversing the cutting side of the paper so both points are cleaned.

Adjusting Armature Spring.—When air gaps and circuits are apparently O. K. and cut-out will not close at 8.5 to 9 volts. Release tension on armature spring. With weak springs tension will allow high reverse current on opening and too much tension will allow opening before zero current is indicated on meter. When cut-out closes at say seven volts, increase the spring tension until cut-out closes at 8.5 to 9 volts. Connect battery wire to cut-out and speed engine up until ammeter shows ten amperes charge. Stop engine and observe ammeter. If reverse current shows too high on opening, slightly increase spring tension until reverse current does not exceed four amperes.

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CHAPTER XIII

THE STARTING MOTOR

Its Location and Purpose.—The starting motor is located on the left side of the engine. Its purpose is to crank the engine until it starts to run on its own power.

Construction.—The construction of the starting motor is very similar to that of the generator, except that it has four brushes, and the armature and field coil wires are much larger. There is also a difference in the bearings, the starter having babbitt bearings while the generator has ball bearings. The reason for the difference in bearings is that in the generator the bearings are in action all the time the engine is running while the starting motor bearings are in action for a few seconds only at a time.

Action.—When using the starting motor to start the engine, retard the spark, turn on the ignition, pull out choke lever on instrument board and press heel button in floor board. Pressing the heel button closes the starting circuit. This circuit starts from the positive side of the battery on the foot-switch, through the foot-switch when the circuit is closed, to the terminal on the starting motor. At this point the current is divided, half of it going through the field coils on one side and the other half through the field coils on the other side. The reason for this division of current is, that having two circuits through the field coils there is less resistance offered to the flow of current. After the current has passed through the field coils it passes to the leads, to the positive brushes, to the commutator, to the armature coils or flat wires which are arranged similar to the coils

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on the generator armature, then to the negative brushes which are grounded, through the ground or metal of the car to the negative side of the battery completing the starting circuit.

As the current flows through the circuit it passes through the field coils magnetizing the cores, it then passes on to the armature coils and as the current passes through them poles are set up in the armature core, the same as in the generator only much stronger. It is the strength of the magnetic attraction and repulsion of the field poles to the armature poles that causes the armature to revolve.

When the starting motor is running light or without a load it will draw about seventy-five amperes or less, depending upon the internal condition of the starting motor. When the armature is connected to the flywheel by the bendix, it requires a current of from 250 to 600 amperes to overcome what is known as the stall torque. The current flow depends upon the compression in the cylinders and the stiffness of the engine bearings. It is for this reason that the starting motor is connected to the battery with a heavy cable, because as stated in the electrical principles, the carrying capacity of a wire depends upon its cross-sectional area. Judgment should be used in using the starting motor to start the engine. With only an 80 ampere hour battery and using from 250 to 600 amperes to start the engine it may readily be understood that a continued pressure on the starting switch would discharge the battery very quickly.

Troubles.—Ninety per cent of the trouble with the starting motor is due to the condition of the battery. If the starter fails to operate, the battery should be tested, see that all connections are clean and tight, and the starting switch in good condition. If connectors or terminal posts are corroded, scrape them and coat them with vaseline. Test the battery with a hydrometer and volt-meter, if found to be O. K. short across foot switch terminals, this will determine if the trouble is in the foot

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switch. Shorting across the foot switch terminals should only be done as a last resort before removing the starting motor from the car.

When shorting across foot switch terminals if an arc is produced and the starting motor does not operate it indicates a stuck bendix due to a bent shaft or the shaft may be seized in the bearing.

Systematic Trouble Hunting.—Remove the starter and place in a vise. The vise should be connected to the negative side of the battery for the ground return. Next connect a heavy starting cable to the positive side of the battery, the other end of this cable should be connected to a 1,000-ampere shunt with a 1,000-ampere meter connected to the two small terminals on the shunt, then connect another cable between other end of the shunt and the starting motor terminal.

When connected in this way the starting motor should run and the ammeter should show not more than 75 amperes.

1. If a high reading is shown and the armature does not rotate, this is a grounded field coil.

2. If it shows a high reading and the armature revolves slowly it indicates a grounded armature.

3. If the armature revolves slowly and jerkily with a high meter reading it indicates a shorted armature.

4. When the armature cannot be turned by hand and the meter shows a high reading the babbitt bearing is seized.

5. If the commutator is black and an arcing is seen at the brushes this is an indication of too much oil on the commutator.

Repairs.—To repair a grounded field coil remove coils and examine for a broken insulation, clean the coil thoroughly with high test gasoline and let dry. When dry repair broken insulation by wrapping with cotton tape enough to cover bare spot. To fasten end of tape use a very small amount of Le Page's glue. Use orange shellac thinned down with wood alcohol to insulate.

In assembling field coils and pole pieces a special tool must be

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used to hold the pole pieces in line to prevent armature from striking.

2. If the armature is shorted or grounded it should be returned to the Company's branch for credit.

3. If the bearings are seized they should be removed and replaced with new ones. New bearings should be reamed out. A liberal amount of grease should be placed on the end of the shaft before reassembling armature to brush and cover.

The old style bronze bushing with felt washer should be replaced with the new style bushing which is longer and has more oil grooves cut on the inside.

4. If the commutator is burned, remove armature mounting bracket and clean commutator. If the commutator is rough, place in a lathe and take a light cut.

If polishing is all that is necessary use No. 00 sand paper. Resand brushes and reassemble.

To straighten a bent shaft place in a lathe and use dial indicator. If trouble is experienced with the bendix return it to the company's branch for credit.

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CHAPTER XIV

THE STORAGE BATTERY

A large percentage of the trouble in the electrical starting, and lighting, and ignition system on the automobile can be traced to the storage battery. The storage battery requires careful and frequent attention and if given such will not require a great deal of time or labor to keep it in good condition.

There is an erroneous idea amongst owners and also a great number of repairmen, that electric current is sent to and stored up in a storage battery, the result of taking the word "storage" too literally. Another idea quite prevalent among owners in general is that the storage battery is a complicated and delicate piece of equipment and being ignorant of its construction they naturally think it is best not to tamper with it at all.

Principle of the Storage Battery.—If two unlike metals are placed in acid and a connection made between them, a current of electricity will flow, from positive to the negative, or from one of higher density to one of lower density until the charge in each one is equal; the flow is very slight however and a very delicate instrument is required to register it. The action of the cell is the same, the plates are of different material, that is, the negative plates differ from the positive.

Difference in Plates.—The positive plate has an active material united with it or, compressed into it called peroxide of lead, and the negative plates have what is known as sponge lead. The difference between the positive plates and the negative plates can very readily be seen, the positive being the darker of the two and somewhat of a rust color.

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Cells, How Connected and Their Voltage—The word battery suggests a number or group of something and it is true when applied to an electrical appliance, for a battery is a group of cells, usually three or more, depending on the pressure or voltage the system is designed to operate on, each cell has (when fully charged) about 2.2 volts pressure and the voltage adds when connected in series, which means when the positive electrode of one is connected to the negative of the adjoining cell, the current passing through all of the cells, therefore, a three cell battery will have a pressure of six volts and so on.

Composition of the Cells.—The cell is composed of a hard rubber jar, a number of lead plates, wood separators and a solution of sulphuric acid and water called electrolyte.

Arrangement of Plates in Cells.—The plates in the cell are arranged in groups, one group being positive plates and the other group negative, but the individual plates are arranged alternately, i. e. the positive plates fit into the negative plates like a dovetailed joint, between each two negatives we have a positive plate, therefore there is one more negative plate than positive.

The plates are not permitted to touch each other, there being a thin strip of wood between each two plates, this wood is called a separator. If the plates come in contact with each other in any way, the cell will be short circuited. The plates are called elements.

Electrolyte.—Water at 60° F. has a specific gravity of I.

Sulphuric acid has a specific gravity of 1.835.

To make "Electrolyte" mix acid and distilled water until the Hydrometer shows a gravity reading of 1.275 to 1,300. Use about five parts of water to two parts of sulphuric acid. The water must *be distilled (not boiled)* so that all mineral substances will be removed.

When mixing "electrolyte" use a glass jar or earthenware crock, if a metal vessel is used it should be lined with lead.

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Care should be taken in mixing the electrolyte, be sure and always pour the acid into the water and pour it slowly, because the mixing of the two fluids creates heat by chemical reaction and the jar may be broken. There is also danger of splashing from the acid, which will burn the skin and eat holes in the clothes.

Action of the Cell on Discharge.—When the circuit is closed between the positive and negative plates the acid in the electrolyte unites with the active material of the plates, causing a current of electricity to flow from positive to negative, and in doing so causes lead sulphate to form on the plates. The amount of sulphate deposited depends upon the length of time the cell is on discharge, and also the rate of discharge.

The plates are completely covered as the cell approaches the "discharge" state which means most of the sulphuric acid has united with the plates, leaving the electrolyte mostly water. This is why the specific gravity of the electrolyte is lower.

It should be noted here that the battery should be kept fully charged at all times, especially in winter, as the efficiency of the battery is lower then, and it is liable to freeze, which is almost impossible when batteries are fully charged.

It should be clearly understood that it is the chemical action on the plates which produces the electricity and causes the current to flow when the circuit is closed. Plates becoming sulphated is a natural thing and should not cause alarm, but, the sulphate should be removed before it becomes set or hardened. This is done by sending a direct current through the battery in the opposite direction. The acid will then be driven out of the plates and back into the electrolyte, removing the sulphate and raising the specific gravity. This is called "Charging".

A battery should not be discharged so that the gravity reading will be under 1.150.

The voltage of a cell when fully charged is about 2.2 volts, and when they show only 1.7 they are practically discharged.

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The current or amperage that will flow from a battery when connected in series is the same as though there were only one cell connected, but the voltage adds in series, that is, one cell should produce 2 volts; two cells, 4 volts; 3 cells, 6 volts and so on.

The capacity of a battery is expressed in ampere hours which means the battery is capable of producing a certain amount of current for a certain length of time. An 80 ampere-hour battery will produce 1 ampere for 80 hours; 2 amperes for 40 hours; 10 amperes for 8 hours; and 80 amperes for 1 hour. Although the latter would not be practical as it might cause the plates to buckle.

If a battery is put on a heavy discharge without periods of rest it will rapidly discharge. So when starting the engine, if it does not start to run on its own power after the starter has turned it over several times, the starting circuit should be opened and the battery given a short interval of rest before attempting it again. And as soon as the engine is started the charge should be put back into the battery as soon as possible. The charging rate is very small, however, compared to the rate of discharge on starting, the discharge will be somewhere between 120 to 200 amperes, and it may be more, depending on the stiffness of the bearings and the amount of compression, but the charge rate is usually about one-tenth of the ampere-hour capacity which in an 80 A. H. battery would be around 8 amperes. (The Ford however ranges from 8 to 14 amperes on charge).

Under ordinary starting conditions it takes about one-half hour of steady charging to replace the charge in a battery what is taken out for one starting, so one can readily see when a car is being started very often that the generator on the car will not keep the battery fully charged but on the other hand, when a driver is doing a lot of long driving like touring around the country and the engine is being run for hours with one starting, if the charging rate is not cut down the battery will be over-

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charged. By turning on all the lights the charge rate will be cut down to some extent.

The electrolyte should be kept above the plates at least 1-8 in. If it falls lower than 1-8 in. only distilled water should be added. Acid does not evaporate, and unless the electrolyte is spilled or the jars are cracked and the electrolyte leaks out the acid never has to be replenished. Should some of the acid be spilled, the cells should be filled with 1.300 electrolyte and put on charge until fully charged, then take a hydrometer reading and it should be between 1.275 and 1.300, not more. If it is more it is an indication of too much acid, therefore, draw off some of the electrolyte and add distilled water, then put the battery on a slow charge rate for three or four hours to be sure that it is fully charged.

A battery should never be allowed to discharge under 1.150 and the cells should not vary more than 25 points, if they do, correct the reading as explained above and watch it closely by taking frequent readings and if that does not remedy it, the battery should be taken to a battery service station, as it is a sure sign of internal trouble.

As a battery approaches the discharge state the plates become coated with sulphate and if allowed to remain that way long there is danger of the plates being short circuited.

A battery should be put on charge from an outside source occasionally and given a long slow charge of about five amperes for 24 hours, and if it heats up the rate should be cut down to 1 or 2 amperes. One ampere can be sent through a battery constantly for some time with good results.

Four Reasons for a Battery Sulphating.—Under charge, excess acid, short circuits; and dry outs.

If one of the cells seems to need to be filled more often than the other cells it may be caused by cracked jars allowing the acid to leak out.

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The cells are made of hard rubber which breaks quite easily if dropped or if the hold down clamps become loose, or if it becomes frozen. The latter can be avoided if the battery is kept charged.

Battery Tests.—When water is added to the cells of a battery, the addition should be made just before the battery is to be charged; the hydrometer reading should not be taken after water has been put into the battery until after it has been on charge for some time, because the sending of the current through the battery is the only means of thoroughly mixing the water and acid.

In order to get a correct hydrometer reading it should be taken when the temperature of the electrolyte is 70 deg. F.

Voltage Tests.—To make a voltage test of a battery it should be put on discharge for ten or fifteen minutes by turning the lights on or connecting a resistance across the positive and negative connections of the battery so that a small current will flow. Then by taking a 30 volt scale of a Weston Voltmeter and connecting the points from positive to negative the meter should show a reading of six volts or more, and by using a three volt scale across the connections of the separate cells they should show a reading of two volts each.

Never use an Ammeter to test a battery because it is an instrument of low resistance and will be burned out. If the cells do not show a voltage of two volts each after they have been on charge for ten or fifteen minutes it is an indication of internal trouble and this is the only good way to distinguish a damaged cell from one that is discharged.

If a battery is to be given good care it should be overhauled and cleaned once a year. The top of the battery should be kept dry and clean at all times and the connections kept tight and greased with vaseline.

To clean the battery, first tighten the filler caps, then take

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a strong solution of baking soda and water and use a brush to cover the top of the battery with the soda solution. Allow it to stand until the top is covered with foam, then take a cup of cold water and dash across the battery to wash off the foam, then repeat the operation until it stops foaming when the solution is applied.

It will be necessary to add water to the battery more often in the summer time on account of hot weather causing the water to evaporate more rapidly.

If the equipment fails to operate, take a hydrometer reading to determine if the battery is discharged and if so it should be taken off immediately and given a long slow charge. When the charging circuit is flowing at a normal rate and all the cells are gassing or bubbling and there has been no raise in temperature for four or five hours the battery is fully charged, providing the hydrometer and voltmeter readings are O. K.

When the battery is being charged the temperature of the electrolyte should not be over 110° F. To prevent the battery from heating the charging rate can be cut down.

It requires about 24 hours to charge a completely discharged battery. Only direct current can be used for charging; if only alternating current is available it will have to be changed into direct, either by motor or generator or with an Arc Rectifier.

Always connect the positive wire of the charging circuit to the positive connection of the battery.

If in doubt as to which is positive and which is negative put some salt in a cup of water and place the ends of the two wires in the water, but do not allow the wires to touch each other. The wire from which the most bubbles come is the negative.

In connecting up lamps for resistance to charge the battery they should be connected in parallel series. On a 110-volt circuit one 16. C. P. lamp will permit but 1-2 ampere flow through it and two 16 C. P. lamps connected in parallel series will allow one ampere to flow. One 32 C. P. lamp will permit

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one ampere to flow; and one additional ampere will flow from each 32 candle power lamp that is cut in. Therefore, if a battery is to be charged at a five ampere rate, five 32 C. P. lamps should be used.

Questions And Answers On The Starting And Lighting System

Q. How many units are there in the F. A. Starting and Lighting System?

A. The F. A. is a two unit system.

Q. Is it a single or a two wire system? Explain and give the advantages.

A. It is a single wire system. Which means just one wire goes to each piece of equipment and the return circuit is through the ground or metal of the car. The advantages are—simple, saving of material.

Q. Which is the Starting Motor and how is it distinguished from the Generator?

A. The starting motor is located on the left side and is attached to the transmission cover. The motor can be distinguished from the generator by the long shaft which the Bendix assembly is attached to.

Q. Define the following—volt, ampere, ohm, watt, high tension, low tension, direct and alternating current.

A. The volt is the unit of electrical pressure or amperes times ohms. The ampere is the unit of current strength or flow, or volts divided by ohms. The ohm is the unit of electrical resistance, or volts divided by amperes. The watt is the unit of electrical power, or volts times amperes. High tension is high voltage. Low tension is low voltage. Direct current is current flowing steadily in one direction. Alternating current flows to and fro, or reverses its direction twice per cycle.

Q. Which side of the system is grounded?

A. The negative side of the Ford system is grounded.

Q. What is the difference between a ground and a short?

A. A ground may be a short if it permits the current to return to the source without doing the intended work or in other words the ground may be unintentional. An intentional ground is a permanent connection to the metal of the car to permit the current to return to the source without using an individual

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wire. A short is an unintentional metallic connection which permits the current to return by a shorter path than the one intended.

Q. What is the difference between magnetism and electricity?

A. Electricity and magnetism are not the same thing although they are very closely related. Magnetism can be produced with electricity and electricity can be produced by magnetism, but a good proof that they are not the same is the fact that copper is one of the best conductors of electricty but it is a magnetic insulator, or that is to say magnetism will not be conducted through copper.

Q. What is a permanent magnet? An electro magnet?

A. A permanent magnet is a magnet made of a piece of hard steel for when a piece of hard steel is magnetized it retains the magnetism permanently. An electro-magnet is usually a piece of soft iron or a bundle of soft iron wires with a coil of wire wound around it, and an electric current sent through the coil, the magnetic field which is built up about the coil when the current is flowing will magnetize the core and it will remain magnetized as long as the current flows, but as soon as the current is turned off the magnetic field dies out and the core being made of the soft iron loses its magnetism almost immediately.

Q. What is the purpose of the starting motor?

A. The purpose of the starting motor is simply to crank the engine over until it starts running on its own power.

Q. What and where is the Bendix assembly?

A. The Bendix assembly is a device which automatically connects and disconnects the starting motor to the flywheel of the engine. It is located on the end of the motor armature shaft.

Q. What kind of bearings are there in the motor?

A. The bearings in the motor are made of babbitt and bronze and because the motor is only run for a short time, or just long enough to get the engine started, there is very little wear.

Q. How much lubrication does the motor require?

A. None.

Q. What would happen if the engine should back-fire when the motor is cranking it?

A. Care should be taken not to advance the spark too far when the motor is cranking the engine because if it should back-fire

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the starter may be broken or at least the armature shaft sprung out of line.

Q. Why is it necessary to have such a large wire to carry the starting current?

A. At the moment the starting circuit is closed there is a heavy discharge on the battery and therefore it requires a heavy wire to carry this current without having it heat up. The carrying capacity of a wire depends upon its cross sectional area.

Q. Trace the starting circuit.

A. The starting current is produced in the battery by chemical action, and flows out at the positive terminal to the foot switch, through the switch when it is closed then through the cable to the terminal on the top of the motor, then through the field and armature coils and grounded to the frame returning through the frame to the negative side of the battery.

Q. Why are there 4 brushes in the motor and only 3 in the generator?

A. There are four brushes on the motor commutator, two positive and two negative; this is done because of the heavy current, and to cut down the resistance as much as possible. On the generator there is just one positive and one negative of the main brushes, the small brush is the field brush and it gathers the current that flows through the shunt field which magnetizes the field poles.

Q. How is the motor tested for power?

A. The power of the motor is tested in torque pounds, each one is required to have a power of from 14 to 16 torque pounds. In other words the motor is connected up to a shaft which has an arm one foot in length keyed to it at right angles, the other end of the arm is attached to a pair of scales. When sufficient power is applied to the shaft to cause the scales to register one pound, the power applied is said to be one torque pound. When a Ford starter is connected up in a device of this kind and the current of a storage battery is sent through it, the turning power of the armature shaft will cause the scales to register from 14 to 16 pounds.

Q. If when you press the foot switch the motor does not start, where would you look for trouble?

A. If the motor does not start when the foot switch is closed, examine the connections, then, see that they are tight and not

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corroded, then, test the battery to see that it is not discharged; next, examine the brushes to see if they are making good contact with the commutator, and that the commutator is clean and in good condition, also see that the Bendix is not stuck. If all these conditions are O. K. the motor should run. If it does not, examine the foot switch and if it is all right the trouble must be in the internal construction of the motor.

Q. What is meant by series wound?

A. Generators are said to be shunt wound and motors are said to be series wound. In a series wound machine all of the current is sent through the field coils or the coils that are wound around the field poles, this is done to magnetize the poles as much as possible, because it depends upon the strength of the magnetic field as to how much turning power the motor will have.

Q. Explain the action of the Bendix.

A. The Bendix assembly is a device to automatically connect and disconnect the starting motor and the engine. It has a spur gear which has a spiral thread in its bore and it meshes with a spiral thread on the shaft, when the circuit is closed through the starter the armature starts to rotate which causes the bendix assembly to travel along the starter shaft and the teeth of the starter gear come into mesh with the gear teeth on the fly wheel, the motor then turns the engine over until it starts to run on its own power, then the flywheel gear starts to run faster than the starter gear which forces the starter gear along the spiral thread and out of mesh with it.

Q. What is the purpose of the generator?

A. The generator is a small dynamo which is driven by the engine and produces an electric current which is sent through the storage battery to replace the charge which was taken to start the engine or to run the lights and ignition.

Q. What kind of bearings are in the generator?

A. The generator is in operation whenever the engine is running. Therefore, it is necessary that the generator have better bearings than the motor which is only in operation for short periods with long intervals, so the generator armature is mounted on ball bearings.

Q. How much lubrication does the generator require?

A. The generator bearing on the gear end of the armature shaft

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is lubricated from the oil pipe which oils the time gears, the rear bearing is oiled from the oil plug over the rear bearing. It only requires a few drops of some good grade of oil occasionally, as the general tendency is to oil the generator too much.

Q. What prevents the battery from being overcharged?

A. There is nothing on the car to prevent the battery from overcharging, although the regulator keeps the output of the generator at a constant rate of flow regardless of the rate of speed at which the generator is being driven.

Q. Name five things which would prevent the ammeter from showing charge when the engine is running.

A. Cut-put points too far apart.
Open circuit between generator and battery.
Loose or stuck brushes in generator.
Dirty commutator.
Ammeter not working properly.

Q. Trace the charging circuit.

A. The charging current is built up in the generator and flows out of the terminal on the top of the generator housing to the cutout, through the cutout points when they are closed, through the ammeter to the terminal block, to the foot switch, to the battery, to the ground, back through the frame to the generator.

Q. What kind of regulation is used on the Ford car?

A. The generator has what is known as third brush regulation to keep the current from building up at high speed, this is accomplished by field distortion, or, in other words, the magnetic attraction and repulsion of the poles that are produced in the armature core, to the field poles distort the magnetic lines of force out of the path that they would ordinarily or naturally follow (that is, directly from the north to the south pole), in the direction of the rotation of the armature, and, the greater the speed the greater will be the distortion, and the greater the distortion the less number of lines of magnetic force will be cut by the coils which feed the shunt field, and consequently, the field poles will not be energized to such a great density, or, the field magnets will not be as strong as they would be if the magnetic lines were not distorted.

Q. Is it necessary to have a magneto in connection with the starting and lighting system?

A. No, the magneto is not necessary on the cars where the start-

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ing and lighting system is used, the battery current can be used for ignition.

Q. How do you account for the wire which carries the charging current to the battery, being attached to the cable carrying the starting current to the motor?

A. The wire carrying the charging current to the battery is attached to the starter cable to save wire. It also is necessary to attach the charging wire to the same battery terminal that the starting current flows out of i. e., positive terminal.

Q. What is meant by shunt-wound?

A. By shunt-wound we mean that the current which flows through the field coils is only a part of the output of the generator. If a water main is tapped and a small pipe connected to it a certain amount of water will flow through the small pipe under the same pressure as the water flowing in the large pipe but less water will flow through the small pipe in the same length of time because there is less resistance in the large pipe. The same condition exists in the shunt wound generator as in the water main, the large pipe represents the out side or charging circuit and the small pipe represents the shunt field winding, and because of the fact that only a part of the current flows through the field coils it is plain to see that the field poles will not be magnetized as strongly as they would be if a heavier current was flowing through them. The out put of the generator depends upon three things, viz. the strength of the magnetism, the speed of the armature, and the number of turns of wire in the armature coils. It is necessary to cut 1,000,000,000 lines of magnetic force per second to produce one volt.

Q. Which circuit is closed all the time?

A. The shunt field is closed at all times. This is the circuit which energizes the field poles.

Q. How would you increase the charging rate?

A. The charging rate can be increased *by moving the third brush on the generator in the direction of the rotation of the armature.*

Q. What is the difference between a magneto and a generator?

A. The difference between a magneto and a generator is, the magneto has permanent magnets and the magnets or poles of the generator are electro-magnets.

Q. Why do they use wire coils on the generator armature and copper bars on the motor?

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A. The carrying capacity of a conductor depends upon its cross section, so it can be plainly seen that the heavy current which flows through the motor at the time of starting would require a much heavier wire than the current produced by the generator for charging.

Q. What is the purpose of the cut-out?

A. The cut-out is simply an automatic switch to close the charging circuit when the voltage of the generator overcomes or exceeds that of the battery. It also opens the circuit when the engine stops to prevent the battery from discharging through the generator.

Q. How is the cut-out tested?

A. The cut-out is tested for closing at 7½ volts or about 700R.P.M. of the generator and for opening at 0, or when there is no current flowing to the battery.

Q. How many windings are there on the cut-out?

A. There are two coils of wire wound on the cut-out core, the voltage of fine coil of 1,300 turns and the series or heavy coil of 10 turns.

Q. What causes the cut-out points to close?

A. The fine coil is the voltage coil and the voltage circuit is always closed. As soon as the engine starts to run the generator starts to build up and a small current starts to flow through the shunt field circuit, and this current flowing through the 1,300 turns of the voltage coil magnetizes the core of the cut-out and pulls the points together and they remain closed as long as there is any current flowing to the battery, because the charging circuit flows through the series coil which is wound on the core in the same direction as the voltage coil. The two coils work together and magnetize the core to a greater strength. As soon as the current stops flowing the core loses its magnetism and the spring pulls the points apart.

Q. What is the purpose of the battery?

A. The battery is a means of storing up electrical energy for operating the starter and the lights when the engine is not running.

Q. What would be the result if the battery was removed from the car.

A. If the battery were removed from the car and the charging current not grounded and the engine started the charging circuit would be broken and the current would not be permitted to flow

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through it. In that case all of the current would be forced through the shunt field circuit and the voltage would be built up which would cause the generator to overheat and perhaps burn the insulation off the field or burn out the voltage coil of the cut-out.

Q. What attention should the terminals and connections have?

A. All connections should be kept tight and all terminals should be kept clean and greased with vaseline.

Q. What is the voltage of the battery used on the Ford?

A. The battery used on a Ford car is a 6-volt battery.

Q. What care does the battery require?

A. The battery should be tested with a hydrometer about once a week. The electrolyte should be kept above the plates at all times. The hold down clamps should always be kept tight. Never allow the battery to be discharged below 1.150 and preferably 1,200. In cold weather it should be kept as nearly charged as possible because a fully charged battery or one nearly so will not freeze unless it is extremely cold weather.

Q. Is the current stored in the battery?

A. The contents of a storage battery will produce electricity by chemical action when the circuit is closed between the plates but there is no current stored in the storage battery.

Q. Explain the action of the battery on discharge and charge.

A. On discharge the circuit is closed through the piece of apparatus to be operated at that instant the two different kinds of metal come in contact with each other and the action of the acid solution or "electrolyte" on the different metals cause a current of electricity to flow from positive to negative through the circuit, and while the current is flowing the acid in the electrolyte is being absorbed into the plates. On charge a direct current is sent through the battery in the opposite direction from which the charging current flowed. This causes the acid to be driven out of the plates back into the electrolyte.

Q. How is the battery tested?

A. The battery should be tested, both for voltage and gravity, for the voltage test each cell should show 2 volts and not less than 1.7 volts on the volt meter. The gravity is tested with the Hydrometer, the electrolyte should not be over 1,300 when the battery is fully charged and it should not fall below 1.150 at any time and 1,200 is preferable.

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Q. How long does it take to replace the charge which was used for one starting?

A. It requires about 30 minutes of steady charging to replace the charge in the battery which was taken for one ordinary starting.

Q. What is the amperage or rate of current flow when charging the battery?

A. The maximum charge rate is regulated in the Ford from 8 to 12 amperes regardless of the speed the engine is running at for an 80 ampere hour battery.

Q. How much current (approximately) flows from the battery when the starter switch is closed?

A. When the starting switch is closed the discharge from the battery is from 120 to 200 amperes and perhaps more, depending on the stiffness of the bearings and the amount of compression in the engine.

Q. What will prevent the battery from freezing?

A. If the battery is kept fully charged or nearly so, there is no danger of it freezing.

Q. Does it make any difference how the battery is placed on the car with regard to positive and negative?

A. The negative side of the Ford system is grounded so it is necessary to ground the negative side of the battery.

Q. What is the meaning of ampere-hour?

A. The capacity of the battery is spoken of in ampere-hours. The Ford is an 80 ampere-hour battery, which means it is capable of producing 1 ampere for 80 hours or 2 amperes for 40 hours, or any other equivalent.

Miscellaneous

Q. Trace the lighting circuit.

A. If the lights are operated from the battery, the current flows from the positive side of the battery to the terminal block, to the ammeter, through the ammeter to the switch and through the connections of the switch to the various lights, and is grounded through the socket and returns to the battery through the frame. If the generator is furnishing the current for the lights, the current flows from the generator to the cut-out and through the cut-out when the points are closed to the ammeter through the ammeter to the switch and from the switch is distributed to the various lights and is grounded through the sockets, and returns

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through the metal of the car to the generator to complete the circuit.

Q. Why do we have a wire leading to each light bulb on the new system, and only one wire for both head lights on the old systems?

A. In wiring the old style job the light wire is connected to the right head light bulb and the current passes through that light and then across to the other one and through it and is grounded and returns through the metal of the car to the magneto. There is a difference in the present model because the current comes either from the generator or battery and is taken to each separate lamp by an individual wire through the lamp and is grounded in the socket, or in other words the old style lamps are in series and the present types are in parallel.

Q. What is the purpose of the switch?

A. The purpose of the switch is to open and close the different circuits.

Q. What is the purpose of the ammeter?

A. The ammeter is an instrument to indicate the rate of current flow on charge and discharge.

Q. What is wrong if the ammeter shows discharge and the engine is running?

A. If the ammeter shows discharge when the engine is running, it is quite likely that the wires are connected to the wrong terminals on the back, the wire which leads from the cut-out should be connected to the charge side of the ammeter.

Q. Trace the ignition circuit.

A. The ignition current if taken from the magneto flows from the terminal on the top of the transmission cover to the terminal block, to the switch, to the lower terminal on the back of the coil box, to the buss bar which makes connection with the terminal on the bottom of all the coil units, through the primary circuit of the coil to the top terminal of the side of the unit, when the commutator roller is on the segment, through the loom wire to the segment of the commutator, through the roller to the cam shaft and returns through the metal of the engine to the ground side of the magneto. When the switch is on the battery side the current flows from the battery positive to the terminal block, to the switch, to the terminal on the back of the coil box, through the coil, through the commutator loom wires to the segment, through the roller when it is on the seg-

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ment and returns through the metal of the car to the ground side of the battery.

Q. Why are there only nine terminals onthe back of the new coil box?

A. On the old style there were ten terminals on the back of the coil box, the top four are for the loom wires which conduct the primary current to the commutator, the four just below the top four are the terminals to which the secondary wires are attached which carry the high tension current to the spark plugs. Below there are two more terminals; the left one is the terminal to which the magneto wire is attached, and the right one is to connect to the battery if one is used. This is done so the battery current will not be sent through the magneto coils which would demagnetize the magnets in certain positions. On the new system the battery and magneto current is taken direct to the switch and the different connections are made in the switch, and in this way the extra terminal on the coil box can be dispensed with.

Q. Trace the horn circuit. Can you sound the horn with the battery? Why?

A. The horn is operated by the magneto current, which flows from the magneto up the steering column to the switch and when the button is pressed there is a metal contact made which closes the circuit, then the current passes down through the horn wire to one of the terminals on the horn and the other terminal is grounded. The horn cannot be operated by battery current because it is direct current, while the magneto current is alternating and as the current alternates, or builds up and dies out and builds up again in the opposite direction, this causes the core of the coil to be magnetized and demagnetized, which attracts and releases the diaphram. If a direct current is used the diaphram is attracted and held.

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CHAPTER XV.

THE FORDSON TRACTOR.

Relation of Tractor to Automobile.—At first sight it appears to be rather a fortunate coincidence that the man to whom the tractor will prove of the greatest benefit is he who has found most advantage in the automobile—the progressive American farmer. The automobile has proved its worth to the farmer and there is no question but that he has mastered it. He appreciates that it is a piece of machinery and as such can only be kept in satisfactory operating conditions by proper attention.

Size of Tractor.—First cost is naturally the chief item considered in buying a tractor and in this connection true economy is to be found in the selection of a machine that is not only of good quality, properly designed and well built for the work it is to do but that likewise has ample capacity to handle it without overloading.

Cost of Repairs.—The next item to be considered is the cost of repair parts. A farm tractor is just like any other piece of machinery it requires replacement of parts that have become worn, therefore it behooves the tractor owner to take into consideration the kind of parts service available for the kind of tractor he intends buying.

Tractor Service—The fact that the tractor is a machine of utility makes it obvious that the service pertaining to it must be prompt and sure. The Ford Motor Company has always been the recognized leader in the giving of service to Ford car owners, and will maintain that lead in tractor service. Car and tractor service is taken care of by the Company's eight thousand Ford

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dealers and by thousands of other garages authorized to give Ford service throughout the world. The Ford Motor Company appreciates the fact that the loss of a few days' time to the farmer may mean the difference between a good crop and a poor crop or possibly no crop at all.

Degree of Care Necessary.—Before taking up the operation and care of the tractor let us revert for a moment to the comparison between the automobile and the tractor in order to emphasize the difference in the conditions of operation of the two. It is a mistake for the owner or operator of a tractor to conclude that because he can keep his car running for weeks at a time and subject it to the severest kind of service without being called upon to give it more than passing attention at infrequent intervals that the same amount of care will be sufficient to keep the tractor running equally well. The most severe service to which an automobile can be subjected is trifling compared to what a tractor must undergo in plowing ten hours a day. No comparison between the two is possible. The attention demanded in running a tractor is really only comparable to that required in running a stationary engine which is run steadily at full power.

The Fordson Manual.—While mechanical knowledge is not required to operate the Fordson Tractor it is very desirable that the operator should understand his tractor. The Fordson Tractor Manual should be carefully studied in order to eliminate unnecessary calls on the dealer for service in minor adjustments. Unnecessary calls mean added expense in tractor operation.

Breaking in a New Tractor.—The owner of a new car is always cautioned not to drive above fifteen to twenty-five miles per hour and to maintain an oil level above normal during the first five hundred miles the car is operated. By doing this the different parts gradually find themselves and a more satisfactory operating car is the result. The same general rule applies

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to the tractor. A geat deal of difficulty may be avoided in tractor operation by greater care in breaking in a new machine. Close observance of the following rules on the part of the operator will prolong the life of the tractor, saving both time and money.

Correct Lubrication.—The importance of correct lubrication cannot be too strongly impressed on traotor drivers. The proper grades of oil must be used in the engine and transmission. *Engine oil must never be used in the transmission.* The proper oil level must be maintained at all times. Do not forget that lubricating oil wears out and gets dirty and should be replaced frequently. Clean oil will protect the engine bearings, and cut down spark plug trouble. By purchasing high grade lubricants you insure all working parts against premature wear.

The Air Washer.—It is very important that the air washer be kept filled with water at all times. If due precaution is used in filling and cleaning the air washer at frequent intervals, not only will the life of the engine be lengthened, but its power increased.

The Drawbar Cap.—This cap is provided for convenience in hitching. Always hitch to the drawbar cap. Do not hitch a chain or rope around the rear axle housing under any circumstances. When pulling a heavy load, or in case the tractor becomes mired, be sure to keep your foot on the clutch pedal. Do not race the engine or let the clutch in suddenly, as this might lift the front end of the tractor off the ground. Should this happen, release the clutch immediately and this will bring the front wheels back to the ground at once. If the tractor should become mired always pull out in low gear.

Engine Abuse.—One of the worst abuses that can be given the tractor is by racing the engine. Drivers should avoid this at all times. The proper speed to run the engine is one thousand revolutions per minute. This will give the tractor the correct working speeds. When the engine is idling cut the speed down as low as possible and retard the spark. When starting

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do not speed the engine to heat up the vaporizer quickly. This is destructive to the tractor and will not accomplish your purpose.

Changing Gears.—Do not attempt to engage or disengage gears until clutch pedal has been pushed down all the way, nor while the tractor is in motion. When changing gears, if the clutch is not entirely disengaged the teeth on the gears will not mesh readily, and there is danger of breaking off the edges of the teeth so that in time they will not remain in mesh. Always close the throttle to slow down engine when shifting gears.

Braking the Tractor.—Do not run the tractor downhill with the gears in neutral or with the clutch released. Engage the gears either in low or intermediate speed and use the throttle to govern the speed of the tractor. In low gear for every revolution made by the rear wheels, the engine must turn eighty-five times which acts as an effective brake.

Cylinders Missing Fire.—Never attempt to continue the work with the tractor when the engine fires only in two or three cylinders. Besides losing power and wasting fuel it causes raw kerosene to get into the crankcase, thinning the lubricating oil.

Road Speed Data.—The following table shows a comparative approximate of the engine speed, revolutions of the rear wheels and the distance traveled by the tractor when being driven in high gear.

Rev. of engine per minute	Rev. of rear wheels per minute	Feet per min.	Miles per hour
1000	54	594	6 3-4
1185 1-6	64	704	8
1333 1-3	72	792	9
1481 1-2	80	880	10

As the tractor is running 6 3-4 miles at 1,000 R.P.M. which is the rated engine speed, driving at speeds above 6 3-4 miles per hour is causing an overload of the engine, which in time will loosen the bearings or pound them out of round.

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Burning Out of Bearings.—When the tractor has buried itself due to the constant pulling on a load, it is advisable to unhitch, run ahead a short distance, and pull out implement with a chain. When the tractor becomes mired the rear end drops down in the hole and the lubricant runs towards the rear bearings and there is danger of burning out the front bearings if the engine is run with the tractor in this position for any appreciable length of time.

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CHAPTER XVI

THE FORDSON CARBURETION SYSTEM

The Holley kerosene carburetor on the Fordson Tractor is an instrument designed to furnish the engine a mixture of kerosene vapor and air in the correct proportions for combustion and in such condition that the kerosene can be used satisfactorily as fuel. While the instrument is designed primarily for the use of kerosene, it will operate with equal satisfaction on gasoline, benzol or California distillate.

Starting.—As heat must be applied to kerosene to vaporize it, gasoline is used to start the engine. For this purpose the tractor is provided with a small gasoline tank mounted on the right hand end of the air washer and connected to an elbow on the front of the mixing chamber casting, which leads to the shifter valve. This valve can be set in either of two positions one for the starting and one for running In the starting position the valve handle is horizontal and in the running position the handle is vertical. When in the starting position a small projection on the lower side of the handle points to the letter "G" cast on the mixing chamber, and when in the running position a second small projection on the right hand side of the handle points to the letter "K" on the mixing chamber. When in the gasoline position a small hole through the valve connects the fuel line from the small gasoline tank to the choke tube in the mixing chamber so that when the engine is cranked gasoline is drawn up from the small tank and into the mixing chamber, where it is sprayed into and mixes with the air entering the mixing chamber from the air washer, through the large connect-

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ing tube. This furnishes a mixture for starting and for heating the vaporizing tube inside of the exhaust manifold until it is hot enough to run on kerosene.

Shifting to Kerosene.—After the engine has been started and run from one to three minutes on gasoline with the throttle about one-quarter open and spark partly retarded, the shift can be made to kerosene or any of the other fuels listed above contained in the main fuel tank. Shifting is accomplished by turning the shifter valve to the running or kerosene position. It may be necessary to partly or completely close the choker valve immediately after turning the shifter valve, to start the flow of kerosene through the vaporizing tube. After a few seconds the engine should operate satisfactorily and be ready to pull its load.

Kerosene Fuel System.—Kerosene is piped from the strainer attached to the main fuel tank to the vaporizing float chamber. It enters the float chamber through a needle valve controlled by a metal float so that the level of fuel in the float chamber is maintained practically constant at a distance of 1 in. from the top of the float chamber casting. The approximate level is indicated by a groove cast on the inside of the float chamber.

From the float chamber proper the fuel passes in around the adjusting needle and through the restricted hole in the adjusting needle seat. From this point it passes to the spray nozzle, from which it is drawn in the form of a very fine spray or mist, by the air passing the top of the nozzle in response to the suction of the engine. The air passing the nozzle is only a very small percentage of that required to make a perfect combustible mixture with the kerosene and is called the primary air. This air is fed by the small pipe leading down from the air washer elbow.

The mixture of kerosene spray and this primary air passes into the vaporizing tube, which is located in the exhaust manifold in such a position as to be so heated as to effectively vaporize the kerosene and mix it thoroughly with the air. From

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the vapor tube this rich mixture passes through the shifter valve and into the mixing chamber at the choke tube, where it meets and is thoroughly mixed with the balance of the air required to form a perfect mixture. From this point the completed mixture is drawn through the intake manifold into the cylinders.

The amount of mixture entering the cylinders is regulated by the throttle valve located beneath the choke tube in the mixing chamber, its position being controlled by the lever under the steering wheel.

Mixture Proportions.—The correct proportions of fuel and air are maintained at different speeds and throttle openings by means of an automatic air valve located in the upper part of the mixing chamber. This air valve consists of a flanged brass ring sliding over suitable guides. When the engine is idling this valve rests on its seat, the flange around the top of the valve having such clearance in the mixer chamber casting as to admit the proper amount of air to form the correct final mixture when added to the rich mixture coming from the vapor tube. As the throttle opening is increased, the air valve is lifted from its seat by the suction in the mixing chamber, maintaining correct mixture proportions in each position, until at wide open throttle the valve is held at its full height.

Adjustment of Mixture Proportions.—But one adjustment is provided for the mixture. This is the fuel adjusting needle, mounted on the side of the float chamber casting nearer the engine and connected to the dash by a forked rod. Turning this rod to the right closes the needle valve and cuts down the flow of fuel. Turning it to the left opens the valve and permits increased flow. The normal position of the adjusting needle is about one and one-half turns off from its seat. In determining this position proceed as follows:

Turn the adjusting rod gently to the right until an increased resistance to further turning is experienced when the needle valve is closed.

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Then turn the adjusting rod to the left one and one-half turns.

Friction is provided by the coil spring around the adjusting needle so that the rod will stay in any position.

It may be found advisable to close or open the needle slightly from the position described above in accordance with the behavior of the engine.

Rich and Lean Mixture.—The mixture may be too rich, i. e. have too great a proportion of fuel to air; in which case the engine may smoke, foul the plugs quickly, carbonize the tops of the pistons, the valve, and the walls of the compression spaces in the cylinder heads, and possibly dilute the lubricating oil in the crankcase with the fuel, or it may be too lean, i. e., have too little fuel in proportion to the air, in which case the engine may back-fire through the vaporizer, or spark knock heavily as if it were badly carbonized. Back-firing results from a lean mixture because the mixture burns slowly in the cylinder and is still burning when the inlet valve again opens, causing the mixture in the intake manifold to ignite and pop back through the vaporizer. A rich mixture is undesirable for the reasons given, and also because it is wasteful of the fuel. It is indicated also at slow speeds by irregular operation of the engine, accompanied by smoke from the exhaust. The mixture should be run as lean as possible without misfiring or pre-ignition to give maximum fuel economy and maintain the engine in a clean condition.

The best way to adjust the needle valve is to open it about one-half turn more than normal, i. e., about two full turns from its seat, and after allowing the engine to run steadily for several minutes to make sure that it is warmed up and operating satisfactorily, turn the adjusting rod to the right about one-eighth to one-quarter turn at a time, allowing the engine to run one or two minutes after each adjustment, until the engine begins to misfire. Then gradually increase the fuel supply by turning the adjusting rod to the left one-eighth to one-quarter

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turns at a time until the engine reaches its highest speed and no more smoke comes from the exhaust. This usually takes about one-half turn from the point at which misfiring occurs. After the best adjustment has been found the driver should observe the angle of the adjusting rod on the dash so that he may readily secure the same adjustment without several tests, after opening the needle slightly when starting.

Cold Weather Adjustment.—In cold weather it will probably be found necessary to open the adjusting needle about one-quarter turn more than is needed for warm weather operation as a smaller amount of the fuel will flow past the adjusting needle when it is cold, particularly before the engine has been thoroughly warmed up.

Running on Gasoline.—If it is desired to run on gasoline instead of kerosene, the gasoline should be put in the main fuel tank and should be used through the float chamber and vaporizing tube exactly as though it were kerosene. It will be found necessary to close the adjusting needle slightly as gasoline flows more easily than kerosene.

Under no circumstances should the engine be run on gasoline from the small tank through the shifter valve for more than the very short time required to heat the vaporizing tube sufficiently so that it will handle the fuel from the float chamber.

If the main tank runs dry and it is necessary to run on the gasoline in the small tank, it should be transferred to the main tank and used in the regular way. This is to prevent damage to the vaporizing tube through overheating, which might occur if the engine is operated for any great length of time on gasoline from the small tank through the shifter valve, without the rich mixture passing through the vapor tube.

USE GASOLINE THROUGH THE SHIFTER VALVE FOR STARTING PURPOSES ONLY.

Exhaust Shunt Valve.—To enable the driver to control the amount of heat supplied to the vaporizing tube in accordance

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with the fuel being used, and the weather conditions, an exhaust shunt valve is provided. This is a flanged tube of cast iron located within the enlarged section of the exhaust manifold and held in any direct position by means of the spring plunger in the handle of the long lever to the left of the extended portion of the vaporizing tube. When the handle of the lever is down at the lowest notch of the sector on the inlet manifold, close to the word *"on,"* and consequently the shunt valve is raised to its highest position, all of the hot exhaust gas is forced to pass over the vaporizing tube, giving to it and the rich mixture passing through it, the highest temperature obtainable. The valve should be set for starting and for normal running on kerosene.

In very hot weather under heavy load, it may be desirable to move the handle up one or two notches to permit part of the exhaust gas to pass through the valve, which will reduce the amount of heat supplied to the tube.

When running on gasoline from the main tank it may be found best to set the handle about the middle of the sector. The handle should be raised clear to the top of the sector only under extreme conditions such as combination of very hot weather and extremely heavy pulling.

It is doubtful if the average tractor will ever meet conditions which require the shunt lever in this *"off"* position.

Smoke.—If smoke issues from the exhaust pipe when the shunt valve handle is in anything but the extreme *"on"* position, it is almost a certainty that enough heat is not being used and the handle should be moved downward at once.

If smoking occurs with the handle in the *"on"* position it is usually an indication that too much fuel is being used and the setting of the adjusting needle should be investigated at once.

Leakage from Float Chamber.—The flow of kerosene entering the float chamber through the fuel pipe from the large tank

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is automatically regulated by the float raising and lowering the float valve. Should any particle of dirt in the fuel become lodged on the valve seat, thus preventing the valve closing, the level of fuel will rise in the float chamber and the fuel will overflow the nozzle and leak out upon the ground. A few drops of fuel will probably run out and drip from the float chamber each time the engine is stopped. This is due to the fuel in the vapor tube draining back into the primary air passage in the float chamber and should not be confused with leakage due to high level in the float chamber.

If leakage continues beyond the few drops mentioned above, proceed as follows:

1. Swing the spring which holds the float chamber cover in position and also the float chamber cover to one side.

2. Hold the float up so that the needle valve is pressed against its seat and open the drain plug on the bottom of the float chamber about two turns until fuel level has dropped below groove inside the float chamber by at least 1-8 inch.

3. Lower and raise the float several times in succession. This may result in washing dirt from the needle valve seat. The result may be checked by watching the fuel level, which should rise to the groove.

4. If the level still continues to rise, twist the needle back and forth several times putting very light pressure on its top.

5. If leakage still continues, remove the cotter pin inside the float chamber which holds the float lever hinge pin in place.

6. Remove the hinge pins and the float and lever assembly.

7. Remove the needle valve and clean the point if necessary noting its condition. It should be perfectly true and smooth.

8. Remove any dirt on the valve seat by allowing fuel to flow through it freely. If this does not give the desired result, the

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valve seat can be unscrewed bodily from the bottom of the float chamber and cleaned.

Fuel and Level Adjustment.—The level of fuel in the float chamber should be not less than 1 in. and not more than 1 1-16 in. from the top of the float chamber. In case the level is outside these limits it can be adjusted readily by turning the float, which is mounted in the float lever by means of a screw, the lever being clamped to prevent the float and screw being turned accidentally. Turning the float so that the screw projects farther upward from the lever raises the float level; turning the float so that the distance between the lever and float is increased lowers the float level.

Water in Fuel.—The presence of water in the gasoline or kerosene tank, even in small amounts, will prevent easy starting and may cause the engine to misfire or stop. As water is heavier than either gasoline or kerosene, it sinks to the bottom of the tank. In the case of the larger tank, the water will collect in the sediment bulb; it should consequently be drained frequently. In the gasoline tank on the end of the air washer, water will collect in the bottom of the tank and be prevented from entering the fuel line to a limited extent by the strainer to which the fuel line is connected. The tank should be drained frequently by removing the plug just forward of the strainer.

During cold weather, water accumulating in the sediment bulb of the main tank, the fuel lines, or in the float chamber itself, may freeze, preventing the flow of fuel. Should this happen, wrap a cloth around the frozen section and keep saturated with hot water for a time. As soon as possible, drain off the water.

Dirt in the Shifter Valve.—The gasoline passage in the shifter valve being very small, a minute particle of grit or other foreign matter may clog up the hole and prevent the engine from starting. Should this occur, remove the shifter valve cover in which the gasoline elbow is screwed, and with the shifter valve

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turned to the starting position, i. e., with the handle horizontal, run a small wire through the hole in the valve. A strand from ordinary picture cord is small enough for this purpose. In replacing the shifter valve cover, make sure that it is screwed in tight as leakage at this point would cause difficulty in starting. Likewise make sure the elbow is screwed tightly into the cover and that the connection of the gasoline pipe to the elbow is well made.

Dirt in Float Chamber.—Should dirt get into the float chamber it may clog the spray nozzle, causing the engine to misfire, or even stopping it entirely. The nozzle can be cleaned without removing it from the float chamber by removing the plug immediately below the nozzle and running a piece of wire up through it.

Vaporizing Tube Pack Nut.—The upper end of the vaporizing tube is connected to the mixing chamber by means of a stuffing box and a pack nut. It is advisable to try this nut with a wrench from time to time to make sure that it has not worked loose. The packing may be either a specially shaped brass sleeve, specially prepared asbestos rings, or asbestos cord. The tightness of the joint at this point can be tested readily when the engine is running or fuel drawn from the float chamber by squirting gasoline onto the packed joint. If the operation of the engine changes in any way when this is done, a loose joint is indicated.

Adjustment for Idling.—If the engine runs too fast, open the throttle lever adjustment screw until the engine runs at suitable speed.

If the engine chokes and stops when the throttle is fully closed, the adjusting screw should be screwed in, holding the throttle lever farther from the stop boss.

When satisfactory adjustment has been made, tighten the lock screw so that the adjusting screw will remain as set.

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Retard Spark for Idling.—If it is desired to have the engine idle for any length of time, it is necessary that the spark be retarded in order to keep the temperature of the exhaust high enough to vaporize the kerosene. It is, of course, understood that the exhaust shunt valve handle must be in the "*on*" position when the engine is idling.

Test for Air Leaks.—If the carburetor has been disassembled or removed from the engine, it should be tested for air leaks by squirting gasoline, while the engine is running, on all joints which have been disconnected. If the operation of the engine changes, that is, the speed increases or decreases when this is done, an air leak is indicated and the joint should be tightened.

Removing Vapor Tube.—In case it is necessary to remove vapor tube, proceed as follows:

Unscrew pack nut around vapor tube in mixing chamber.

Remove float chamber.

Remove exhaust manifold outlet. This is the casting fastened to the bottom of the manifold.

The vapor tube can now be removed but must be handled carefully to avoid bending or otherwise injuring the thin walled tubing.

The section which extends above the manifold to the mixing chamber is of heavy walled tubing and can be handled with pliers, if necessary.

Replacing Vapor Tube.—If a vapor tube is to be replaced proceed as follows:

1. Pass heavy end of vapor tube through hole in exhaust manifold with shunt valve in the "*on*" position.

2. Place packing nut and packing around vapor tube.

3. Be sure that old packing is removed from hole in mixing chamber.

4. Insert upper end of vapor tube into mixing chamber, pushing it in until it seats.

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5. Insert packing and screw up pack nut tight.

6. Replace exhaust manifold outlet, being sure to have the lower end of the elbow on the vapor tube properly enter through the hole in the manifold outlet.

7. Move the heat shunt valve from *"on"* to *"off"* position, to be sure that it does not rub on the vapor tube.

8. Replace float chamber, being sure that gasket between it and manifold outlet is in good condition.

9. After the engine has been run so as to thoroughly heat the manifold, try the tightness of the pack nut on the upper end of the vapor tube. This should be done occasionally when the tractor is in service.

Replacing Vapor Tube Packing.—Cases have occurred where the vapor tube was not properly pushed up in the mixing chamber and the packing crowded over the end of the vapor tube and partly blocked the passage above it. This could be indicated by lack of power or refusal of the engine to operate under more than half open throttle. If it is necessary to replace packing make sure that the old packing is removed from the mixing chamber and that the vapor tube is held up to its seat when the new packing is installed.

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CHAPTER XVII

THE FORDSON AIR WASHER.

Necessary Care.—It is safe to say that there is no part of the tractor any more important than the air washer, and no part that is any easier to give proper attention.

The air washer bowl should be kept filled with water at all times. Remove the cap at the bottom of the chamber at least twice a day and drain the water. The bowl should then be flushed out by screwing in the bottom cap and pouring a pail of fresh water into it then removing the lower cap. After this replace the cap and fill the bowl with fresh, clean water.

Neglecting the air washer will cause endless trouble and expense. In the first place the air washer furnishes a small amount of vapor which facilitates the operation of the engine and helps to maintain a clean condition in the combustion chambers. In the second place it removes the dust and dirt from the air. If the air washer is neglected this dust and grit will be drawn into the cylinders, wearing the pistons undersize and the cylinder walls oversize and out of round, also destroying the valves. When the pistons and rings are worn undersize, this dirt together with unvaporized kerosene will work through into the crankcase and wear the bearings on the crank and camshafts undersize and out of round. It is very essential that tractor owners and operators should know the importance of keeping this unit in proper condition at all times.

Construction of the Air Washer.—The air washer consists of a cast iron tank with a standpipe in the center through which

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the air enters from the outside. The air is deflected through the water by means of a sleeve which fits over the standpipe and is supported by two floats. This sleeve moves down as the level of the water lowers until finally the sealed end of the sleeve rests over the opening of the standpipe, shutting off the air supply, thereby stopping the engine.

Water Consumption.—The air washer should always be kept filled. When driving the tractor hard it is necessary to add water twice a day as the engine consumes approximately one quart of water per hour when running at 1000 revolutions per minute. If the work is particularly dirty, it is necessary to clean the bowl daily. This is done by removing the drain plug and flushing it with water. To prevent an excess of water being drawn into the cylinders, an air deflector is placed above the surface of the water. Part of the moisture of the air deposits on this deflector and runs back again.

Air Washer Troubles and their Remedy.—Trouble in the air washer is usually noted by lack of power—a rich mixture showing black smoke at the exhaust, even with the needle valves turned lower than normal; or on the other hand a lean mixture requiring the priming valve to be partly closed to have the engine hit evenly.

Trouble in the air washer is often confused with ignition trouble by one who is judging by the sound and running of the engine. The first thing to do if the trouble is indicated in the washer, is to drain the water and flush out the bowl. If this does not overcome the trouble, remove the cover and examine the interior. The cover and float may be removed without taking off the fuel tank. Unscrew the two (tube flange to cover) cap screws. This frees the flange which may be raised off the primary air supply pipe and draw off the main air supply pipe. Next drain the water out of the bowl and remove the four cover-to-bowl bolts, the cover may then be removed, taking care not to

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damage the float. When the cover has been removed take off the deflector, after which the float may be taken out.

If clearance cannot be obtained between the fuel tank and the float, due to the float remaining in a raised position, it is necessary to raise or remove the fuel tank. Take off the fuel tank band on the dash, loosen the nuts on the band on the radiator top tank and disconnect the fuel supply tube. The tank may now be raised up on the dash end sufficiently high to clear the cover. If, however, this does not suffice, disconnect the fuel tube from the sediment bulb and remove the steering wheel; after which the tank may be completely removed.

The float should be examined to see that it does not leak. Usually this may be determined by shaking it and listening for the sound of water inside. See that the guide is not damaged so it will stick on the deflector and that the floats are securely connected to it. Finally see that the floats are not badly collapsed, as collapsed floats allow the float assembly to settle too deep in the water.

Small leaks in the floats may be repaired by soldering. A final test on a soldered float should be made by submerging it in four or five inches of water, holding it down by a weight for a period of five hours or more. Before replacing the float the bowl and air passage in the standpipe should be thoroughly cleaned.

A very important point in the assembly of the fuel system is to have airtight joints. Good gaskets are essential, and the repairman will save time and expense by making sure they are in perfect condition. If there is the least bit of doubt, use new ones. The gaskets should be shellaced to the bowl and cover, making sure that the bolt holes are not covered.

Place float in the bowl, and place a gasket on the bowl. Next, position the deflector on the bowl with the convex side down. This is very important as the deflector will not function pro-

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perly in the inverted position. Furthermore, the deflector acts as a guide for the float assembly, and if it is inverted, the guide of the float does not extend through the opening; thus the float may turn and be held down preventing the engine from starting.

When the deflector has been positioned, place the cover and secure it with the bolts. The tube flange is next fitted over the main air supply pipe and down over the primary air pipe. Here again the repairman should take care to inspect the gaskets between the flange and the air supply pipes. A gasket is then placed between the flange and the cover and they are drawn together with the two cap screws.

If the fuel tank has been removed it should be inserted into the front end and rested on the dash. The dash strap should next be put on and tightened. The repairman should make sure that the lining between the supports and the tank are in good condition or the tank will develop a leak if allowed to come in contact with the metal of the supports.

After installing the steering wheel, connect the fuel supply tube to the sediment bulb, drawing it down with the nut, and the tractor is ready to test.

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